LAKE TURKANA

A REPORT ON THE FINDINGS
OF THE LAKE TURKANA PROJECT
1972 - 1975

VOLUME 2

EDITED BY A. J. HOPSON

Z
FISH
B
74D
HOP

LAKE TURKANA

A REPORT ON THE FINDINGS OF THE LAKE TURKANA PROJECT

1972-1975

GOVERNMENT OF KENYA AND
THE MINISTRY OF OVERSEAS DEVELOPMENT, LONDON.

EDITED BY A.J. HOPSON

Volume 2 of 6 Volumes

MUS. NAT. HIST.
MAY
PURCHASED

OVERSEAS DEVELOPMENT ADMINISTRATION
LONDON
1982

Published 1982 Institute of Aquaculture
University of Stirling
STIRLING FK9 4LA
Scotland

Copyright © 1982. Crown Copyright Reserved.

ISBN 0 - 901636 - 41 - X

Produced, Printed and Bound at the University of Stirling

CONTENTS

		Page
	Forward	i
	Preface	iii
	Acknowledgements	vi
Chapter		
1	Geographical, physical and chemical aspects of Lake Turkana	1
2	Studies on algal dynamics and primary productivity in Lake Turkana	109
3	Studies on the zooplankton of Lake Turkana	163
4	A study of the prawns *Caridina nilotica* (Roux) and *Macrobrachium niloticum* (Roux) in Lake Turkana	247
5	The fishes of Lake Turkana	281
6	The commercial fishery of Lake Turkana	349
7	Shore survey	557
8	Openwater surveys	581
9	The biology of cypriniform fishes	751
10	The biology of siluriform fishes	1017
11	The biology of perciform fishes	1283
12	The food of zooplanktivorous fishes	1503
13	Conclusions and recommendations	1563
	Main Appendix 1 An annotated checklist of Invertebrates recorded in Lake Turkana	1589
	Main Appendix 2 Specification of the welded steel research vessel "Halcyon"	1603
	Index	1605

VOLUME 2

Chapter 6 The Commercial fishery of Lake Turkana
Chapter 7 Shore survey
Chapter 8 Openwater surveys

CHAPTER 6

THE COMMERCIAL FISHERY OF LAKE TURKANA

by
P.B. Bayley

CONTENTS

INTRODUCTION

HISTORY AND RECENT DEVELOPMENT OF THE LAKE TURKANA FISHERIES

Subsistence fisheries

The Turkana
The Galeba or Merille
The El Molo

History and development of the commercial fisheries

Expansion of the areas exploited during the period March 1972 to February 1974

Areas exploited and unexploited
Important areas of expansion

COMMERCIAL CATCHES AND YIELDS OF THE LAKE TURKANA FISHERY

Introduction

Conversion factors

Conversion from processed weight to fresh weight

The traffic of fish through co-operative branches

Subsistence fishing and extra-cooperative branches

Subsistence fishing
Extra-cooperative trade

Total yields, regional yields, specific yields and yields per unit area

EFFORT IN THE COMMERCIAL FISHERY

Introduction

Record of Fishermen

Estimations of 'commercial fishing effort' outside the calibration period and of 'total fishing effort'

Fishing craft

Commercial net measurement and gillnetting methods

Discussion and conclusions

THE ESTIMATION OF CATCH PER EFFORT FROM COMMERCIAL FISHERY STATISTICS AND FROM EXPERIMENTAL GILLNET DATA

Introduction

Catch per effort from annual yields

Experimental inshore gillnetting
  - Gillnet specifications
  - Sampling programme
  - Catch per effort: defination and results
  - Diurnal variation in gillnet catches
  - The effects of wind on catch per effort
  - Species selection in relation to mesh size

Comparisons of experimental and commercial catch per effort

Comparisons with previous records of catch per effort

Weekly commercial catch per effort for the major species

NOTES ON THE STATUS OF MAJOR COMMERCIAL SPECIES IN THE INSHORE FISHERY

  - Introduction
  - *Heterotis niloticus* (Ehr.)
  - *Gymnarchus niloticus* Cuv. and mormyrid species
  - *Hydrocynus forskalii* (Cuv.)
  - *Citharinus citharus* (Geoffr.)
  - *Distichodus niloticus* (L.)
  - *Labeo horie* Heckel
  - *Barbus bynni* (Forsk.)
  - *Clarias lazera* C & V
  - *Heterobranchus* sp.
  - *Bagrus bayad* (Forsk.)
  - *Bagrus docmac* (Forsk.)
  - *Synodontis schall* (Bl.-Schn.)
  - *Lates niloticus* (L.) and *Lates longispinis* (Worth.)
  - *Sarotherodon niloticus* (L.), *Sarotherodon galilaeus* (Art.) and *Tilapia zillii* (Gerv.)

GENERAL CONCLUSIONS

REFERENCES

APPENDIX I A checklist of fish caught by Turkana fishermen

APPENDIX II Relationships between important parameters of major commercial fishes

APPENXI III Mean weights (in kg) of different species sold each month to the co-operative branches

APPENDIX IV Analytical methods used in the estimation of fishing effort

APPENDIX V Gillnet selectivity

6. THE COMMERCIAL FISHERY OF LAKE TURKANA

P B Bayley

INTRODUCTION

Until recently, Lake Turkana (formerly Lake Rudolf) was unique among major African lakes in lacking a substantial indigenous fishery. Since 1961, it has been the policy of the Kenya Government to encourage pastoral nomads of the Turkana tribe to take up fishing where drought and famine rendered them otherwise destitute. As a result of this policy a total of nearly 3000 men are now engaged in fishing the inshore areas, chiefly on the west coast in the northern basin of the lake. Co-operatives have been established to market the fish and by 1970, official statistics indicated that the annual yield of Lake Turkana exceeded 4000 tonnes of fish, wet weight.

The purpose of the present investigations was to carry out a detailed study of this recently established fishery which would provide a sound foundation on which management policy could be based. Routine data which form the basis of the study were derived from a network of recording stations established at the co-operative branches. They furnish information on catch, effort and catch per effort for each species of fish, in different areas throughout the year. The results, combined with additional material on commercial fishing gear, experimental gillnetting, extra-cooperative trade, location of fishing grounds and the biology of the fishes concerned, have enabled major trends in the fishery to be recognised. In certain cases such trends are potentially damaging to the long-term success of the industry and a series of management measures have been suggested. Additional information is provided on the relatively minor subsistence fisheries of the Galeba and El Molo tribes.

Field work for the present study was carried out during the period March 1972 to March 1974. The collection of catch statistics which was initiated at the co-operative branches during May-June 1972 has continued under the supervision of the Fisheries Department and use has been made of all available data.

Environmental conditions in the region of Lake Turkana have been discussed in detail in Chapter 1. The strong, prevailing southeasterly winds which blow regularly on most mornings are a factor which particularly affects the fishery. Rough seas during the early part of each day curtail the time available for tending the nets and limit the distance to which the fishermen are able to row offshore in their canoes. Infrequent but heavy rainstorms at times sever the road links between the lake and the remainder of the country, causing delays in the export of fish and in the arrival of essential supplies of salt. However, the climate is ideal for the drying and storage of salted fish.

Communications between Lake Turkana and other parts of the country are illustrated in Figure 6.1. Lorries carrying dried fish converge on Lodwar from all sections of the west shore of the lake. Traffic from the northern sector of the lake passes through Lokitaung. From Lodwar the lorries normally travel over unsurfaced roads to Kitale from where a network of tarmac roads extends throughout East Africa. Filleted-dried and smoked fish were mainly sold in Kenya at the time of the present survey, but dried, salted fish was exported to Zaire via Uganda. Practically no fresh fish was sold away from the lake shore.

Communications between the east and south-east shores of Lake Turkana and potential markets in more populated areas to the South are poor, with the result that road transportation of fish tends to be uneconomical. No fish is exported from the Ethiopian sector of the lake or from the lower Omo to other parts of that country due to the lack of suitable roads.

A checklist of fish caught by local fishermen, together with Turkana and Swahili names,is presented in Appendix 6.1. There is some confusion about the Turkana names for the mormyrid species, which are restricted to the Omo delta and have only recently become familiar to Turkana fishermen. The names of _Barbus bynni_ also lead to ambiguities. The common name is _momwara_ but in northern areas some fishermenuse the name _nabile_ for sexually mature specimens with enlarged and whitish snouts. In the Kerio region the terminology is reversed and _nabile_ is used as a general term for _B. bynni_.

Detailed descriptions of fishes appear in Chapter 5.

HISTORY AND RECENT DEVELOPMENT OF THE LAKE TURKANA FISHERIES

SUBSISTENCE FISHERIES

Three tribes have been involved with fishing prior to commercial development. The present distribution of the Turkana, Galeba and El Molo are indicated in Figure 6.2.1.

The Turkana

Fishing is not new to the Turkana, as a small number have always fished for subsistence, and to supply fish for local consumption by government officials. However, apart from a few rafts made from doum palm logs, there are no indigenous boats.

Basket trapping is the traditional method for catching _Sarotherodon niloticus_ and _Sarotherodon galilaeus_ in their scrape nests. The technique is still used on Lake Turkana largely at Todenyang, Ferguson's Gulf and Kerio Bay. Baskets are also used in the Rivers Turkwell and Kerio to catch mainly _Labeo horie_, _Schilbe uranoscopus_ and _Clarias lazera_ in the course of their migrations to and from the lake.

Harpoons, consisting of a removable barbed iron point fitted to a wooden shaft and also joined to it by a rope are used mainly to catch large _Lates niloticus_ and _Clarias lazera_ close inshore. This traditional gear is still in use but is not so productive as other methods.

Long-lines with baited hooks have also been used inshore for some time, catching mainly _Lates niloticus_, _Bagrus bayad_ and _Clarias_, _lazera_. Formerly bone hooks were used, but since 1961 they have been replaced by imported metal hooks.

The Galeba or Merille

This tribe is centred in the region of the Omo delta and includes a group known as the Shangila (but who call themselves Galeba) who fish close inshore on the east coast as far south as Moite (Fig. 6.2.2). The Galeba use dugout canoes for transport. Their fishing methods include harpoons and longlines. Spears are used in shallow well-vegetated situations, particularly for *Sarotherodon* spp. Large *Lates niloticus* are sometimes shot with firearms. Basket traps are not used traditionally by this tribe.

The term Merille is usually reserved for Galeba living to the north of Lake Turkana in the delta area. Settlement is particularly dense on the west bank of the River Omo just north of the Ethiopian frontier. Since 1972 the Merille have fished increasingly with nylon gillnets following the practice of Turkana in adjacent Kenyan waters.

The El Molo

Originally reported to be encamped on islands in Allia Bay by VON HOHNEL (1894), they are now restricted to Loiengalani on the south eastern shore of the lake and to the two islands in El Molo Bay. They are the only tribe at Lake Turkana which traditionally depends on fishing.

El Molo fishing techniques include harpooning, spearing, hand-netting, and the beach-casting of lures. *Lates niloticus* is the principal species caught by harpooning and beach casting. The hand-nets catch chiefly *Sarotherodon* and are used collectively by a group of fishermen. The group form a circle which is then brought to the shore enclosing the fish, many of which escape. Introduced techniques include beach-seines.

HISTORY AND DEVELOPMENT OF THE COMMERCIAL FISHERIES

Up to 1961, the only commercial development of fisheries on Lake Turkana consisted of small scale beach-seining for *Sarotherodon* spp. in the Ferguson's Gulf area. The salted catch was exported to Kitale together with dried fillets of *Lates niloticus*. Small quantities of fresh fish were purchased by government officers in Lodwar for domestic consumption. Government participation in the fishery was restricted to seine netting initiated by the District Commissioner, Lodwar, in 1945 to provide food for famine relief at Kalokol.

In 1961, the Kenyan Fisheries Department became involved in the fisheries and Mr R R McConnel was posted to Ferguson's Gulf as Fisheries Development Officer, a post which he occupied until 1976.

The problems of the region were considerable, with famine widespread. Government famine relief camps (known as *maskine* camps) were established in the early 1960s, at Lodwar, Kalin (near Lokitaung) and Todenyang. Cast nets were tried unsuccessfully at Todenyang Famine Camp, but trials with gill-nets were encouraging and the catch was distributed as famine relief at Kalokol and later at Todenyang. Slowly, increasing numbers of former *maskine* camp inmates were successfully encouraged to fish. At the end of 1962 Oxfam started a valuable service by buying fish from Ferguson's Gulf in dried fillet form and distributing it to inland *maskine* camps such as Lorugumu. This artificial market gave the fishery a good start, whilst long term markets were being sought and established. The fishing area had extended north of Kalakol to Namudak by 1964.

In April 1965 the Kalokol Fishermen's Co-operative Ltd. was set up with the help of a grant of £75,000 from the National Christian Council. The markets in Western Kenya were very good for dried fillets and from 1966 a lucrative market in Zaire for dried salted fish was opened. Oxfam provided the fishermen with Sesse canoes (a design originating on Lake Victoria).

In early 1968 the Catholic Mission distributed 100 eight inch gillnets to inmates of the Todenyang maskine caamp. Due mainly to border trouble with the Merille in Southern Ethiopia, the camp was moved to Lowarengak in July 1968. A further 50 nets were distributed in August 1968, and the fishing families were by then spread out between Todenyang and Nachukui. From then on the Turkana were able to buy additional nets at half price, and increasing immigration of new fishermen from Lokitaung and Kakuma took place. Dug-out canoes were initially obtained from the Merille until safer craft were available. Prior to the opening of the unofficial Mission Cooperative at Lowarengak on the 1st August 1969, the production of dried fillets had been purchased by the Mission for sale in Kenya. Fillets were bought from the fishermen for KSh 1.20 per kilo, the same as the official price at the Co-operative in Kalokol. In June 1969 salting of fish was started for the Zaire market, and the product was initially bought from the fishermen at KSh 1.10/kg. The Mission sold the co-operative facilities to the Turkana Fishermen's Co-operative Ltd in July 1971.

Meanwhile in September 1969 the Catholic Mission at Kataboi had instigated fishing with two boats, and a branch of the official Co-operative was opened in June 1970. From the end of 1970, fish were being purchased at Elibe by the Official Co-operative in Kalokol. In January 1972 the African Inland Mission opened an unofficial co-operative there, but sold the products to Kalokol as before. At Nachukui a branch of the Official Co-operative was opened in February 1971, and also another at Todenyang in September of the same year.

The Catholic Mission started a scheme at Kerio in September 1971 and the co-operative store was bought from the Mission and made official (under the direction of the Kalokol co-operative) in June 1973.

In conclusion, since September 1971 there have been seven "buying points" on the lake, all situated on the west shore (see Fig. 6.2b). This does not mean that previously certain areas were unfished, since Turkanas are accustomed to walking long distances. However, the opening of "buying points" did result in a marked increase in fishing effort in adjacent areas.

EXPANSION OF THE AREAS EXPLOITED DURING THE PERIOD MARCH 1972 to FEBRUARY 1974

Areas exploited and unexploited

Figure 6.2b shows the extent of the areas fished at the beginning and end of the period. Depth contours and the "buying points" are also indicated. An accurate shore survey was not completed at the time of writing and Figure 6.2b is based on Survey of Kenya maps made prior to the 1962-63 rise in lake level. Resulting changes in shoreline have occurred mainly in the vicinity of the Omo delta and in Allia Bay. The former has been corrected with the aid of photographs taken from the air during October 1973, and the latter region from observations made during cruises on the research vessel HALCYON. For the present purposes, greater accuracy is not important. The areas contained within the shallower contours measured by the author with the aid of a planimeter, are shown in Table 6.1. The values of 15 m are from interpolated contours and are therefore more approximate.

The areas exploited at the end of the study period together with their respective buying points are summarised in Table 6.2.

Since the inshore fishery (that is practically all the present commercial fishery) extends offshore to a depth of about 15 m, the percentage of the lakewide area within that depth at present being exploited regularly is:

$$\frac{943}{2170} \times 100 = 43\%$$

The degree to which it is desirable or indeed practicable to extend this exploitation is discussed in the final chapter.

Important areas of expansion

As can be seen from the map, the most significant changes during the study period have occurred in the Omo Delta area and on the East Shore. Changes in the Omo Delta area resulted from improved relations between Merille and Turkana during the middle of 1973. By the end of that year, many more Turkana families were commuting between the Delta and Todenyang, and Merille families were living on the Kenya side of the frontier at Todenyang. The Merille started to sell fish directly to the Co-operative. This change to more friendly relations was mainly due to marketing facilities in Kenya and to the sale of salt and nets. None of these amenities existed on the Ethiopian side of the border.

The exploitation of the eastern shore from Kalakol began in February 1973 and increased during the middle of the year as a result of reduced catches in the Kalakol area. Fishermen became increasingly confident at undertaking the hazardous canoe crossing and were overcoming a long-standing fear of the eastern shore. Crossings were made via Central Island (the shores of which have produced relatively little fish) and initially exploitation covered the narrow, inshore belt between Moite Bay and the southern extremity of Allia Bay. Later Allia Bay itself was exploited and commercial fishing continued for approximately four months until the beginning of 1974. In January 1974 the control of the new Sibiloi National Park extending from just south of Ileret to the southern extremity of Allia Bay was established, and inshore fishing was effectively prohibited. Fishing is now limited to areas of the eastern shore outside the boundaries of the park.

From a base at Eliye, fishing on the eastern shore between Moite Bay and Otus Island began at least as early as January 1972. Eliye fishermen started to cross the lake earlier than Kalakol fishermen, partly because of a general dearth of fish in the Eliye area and partly because at Lolibekai Point, a few Km south, the lake is at its narrowest. From Kerio, the crossing of the lake to the richer fishing grounds is of much more recent occurrence and, apart from previous isolated journeys, significant numbers of boats began crossing the lake between December 1973 and February 1974.. These crossings are likely to be seasonal, because in Kerio Bay there is a marked improvement in fishing between April and November resulting from river flow.

Exploitation of the shores of North Island has been undertaken by fishermen from Nachukui from about early 1973 onwards.

This concludes a largely qualitative background to the fishery development, which provides a basis on which to assess the catch figures in the following section.

COMMERCIAL CATCHES AND YIELDS OF THE LAKE TURKANA FISHERY

INTRODUCTION

The total yield of fish may be divided into the following categories: (a) trade via all the official and unofficial Cooperative Branches, (b) trade outside the Cooperatives and (c) fish consumed locally by fishermen and their relatives, i.e. subsistence. Most of the yield is traded through the Cooperative Branches, and during the present studies these provided useful bases for stationing Fish Recorders. The section on the traffic of fish through the cooperative branches provides details of the Fish Recorders' duties and presents results up to the end of 1974, while the section on conversion from processed weight to fresh weight explains a system of checking the Fish Recorders' work. Estimates of extra-cooperative trade and of the subsistence fishery are considered. A summary including the total annual yield since 1963 and a breakdown of yields from 1972 to 1974 inclusive, by region and by species, is also shown.

All unqualified values and percentages are in metric tons on a fresh weight basis.

CONVERSION FACTORS

Conversion of numbers of fish to fresh weight and the determination of length frequency distributions

It was most convenient and accurate for the Fish Recorders to count the numbers of each species of fish. With the help of other measurements it was possible to calculate the average weights of the various species concerned. Three separate methods are presented and discussed below:

Method 1. Measurement of opercular bones

With a few exceptions, most of the fish purchased by the Cooperative Branches had their head intact, and with the aid of 'tin-snips' large numbers of opercular bones could be removed easily by the Fish Recorders, and later boiled in water and cleaned. To avoid selection, the Recorders were trained to work through piles of dried fish, discarding only individuals of species not required. This work was done every week at times when fish were not being purchased and continued until a monthly sample of the required size was obtained. Only opercula from the left side were accepted to avoid duplication. Good calibrations between operculum measurements and the total or fork length were obtained from fresh fish,as summarized in Appendix 6 II.9. Significantly better correlations were obtained using total length for Citharinus, Distichodus, Labeo and Hydrocynus but conversions to fork length are available in Appendix 6.II.8 if required.

After applying the appropriate conversions factors, length-frequency distributions were obtained from samples of usually between 100 and 200 opercular bones per species from each Co-operative Branch each month. These data were collected for the following species:- Hydrocynus, Citharinus, Distichodus, Labeo, Barbus bynni and Lates spp. The length frequency distributions have been compared with the current mesh size distributions and the selection ranges of the commercial gillnets (see page 374). They were converted to mean fresh weights using the weight-length correlations summarized in Appendix 6.II.1, and these weights are summarized in Appendix 6.III.

This method was the most accurate of the three and had the added advantage that bones were available for age determination. Attempts at age determination using this material were successful in the case of Citharinus. A major disadvantage was that the procedure was time consuming and required assistants to clean and measure the bones. Furthermore, the small proportion of fish arriving as fillets could not be sampled, since no consistent morphological features were present for measurement.

Species other than Lates were filleted before drying only when there was a lack of salt. The process was not size selective and, provided that samples of whole fish were also available, it was not considered to be a source of error. Fishermen have always received better value for salt-dried rather than filleted-dried fish from the Cooperatives since the trade for the former began. However, with the exception of Kerio, the Branches have mostly rejected large salted-dried Lates niloticus with their heads intact in order to avoid possible damage to the presses used for packing fish. This reduced the economic advantage of salted-dried Lates (minus their heads) over filleted-dried examples. In both cases, neither opercular bone nor direct measurements were possible, and underestimates resulted at all recording stations with the exception of Kerio. Method 3 below outlines a technique used for Lates spp.

Method 2. Direct measurements of salted-dried fish

This system, using a measuring board marked in 1 cm intervals, was used for the species of lesser importance, and was extended to include all important species by the author when he departed in March 1974. Fish Recorders were instructed to avoid selection by working through piles of fish as before, but only measuring those fish which had complete heads and tails. Fork lengths were measured (excepting Lates spp., Sarotherodon spp. and Clarias) since the lobes of the tails were more often missing or damaged. Results were recorded directly on length-frequency data sheets supplied for each species until the required sample size had been reached for the month.

The advantage of this system over Method 1 was time-saving. The work level of the Fish Recorders was reduced and the laborious task of washing, cleaning and measuring bones was no longer necessary.

The disadvantages included possible underestimates due to size selectivity. Larger specimens tended to sustain more damage after drying and a disproportionately high proportion of large fish may have been discarded by the Fish Recorder due to damaged tails. Also the potential sample size was reduced by fishermen removing whole or parts of tails on capture, to identify their fish on landing. It was even more impractical to measure standard lengths on dried fish than on fresh individuals. The paucity of complete large Lates is a further source of error as was the case in Method 1.

The more reliable results using this method are as shown in Appendix 6.III.

Method 3. Estimates from experimental gillnets

Providing that the commercial mesh size distribution and the current catch per effort and mean weights for each experimental gillnet size (covering the commercial mesh size range) are known for a particular region, the mean size of the commercial catch can be estimated for each of the constituent species. It must also be assumed that effects due to other fishing gear exploiting the species are negligible. This method was mainly used for Lates spp. at Todenyang, Kalokol and on the Eastern Shore.

Conversion from processed weight to fresh weight

About 95% of the commercial catch sold to the Cooperative Branches had been split, salted and sun-dried. The remainder was filleted and sun-dried, with a very small amount of the Kerio Branch purchases being smoked whole. Larger quantities are smoked whole and traded outside the Cooperatives. It is necessary to know the respective conversion factors, in order to convert the weight of the processed product to fresh weight. This information was also required for checking the Fish Recorders' reords which are independent of the dried weights registered by the Cooperative Branches during the purchase of fish.

Samples of whole salted-dried Citharinus, Distichodus, Labeo and Lates niloticus from Kalakol Branch were weighed to an accuracy of ±1%, and the left opercular bones were then extracted. The equivalent fresh weight of each fish was calculated using the appropriate opercular bone/length and length/weight regressions (Appendix 6.II.1 and 6.II.9). The results are summarized in Table 6.3. This table shows similar values for four major species, and the apparently significant differences between the conversion factor for Labeo and those for Citharinus and Lates niloticus are probably due to differing storage times. A Cooperative Branch Manager has reported (LARS BO, pers. comm.) that 10 to 15% weight loss during storage of individually checked bales of dried fish is not uncommon. Since the overall range (within the extreme 95% confidence limits for mean predictions) is equivalent to a 52% to 70% weight loss (from the data in Table 6.3.), there is a limit to the accuracy with which fresh weights can be predicted from products whose water content varies.

Monthly conversion factors were also estimated by comparing the total fresh weights derived from the Fish Recorders' data with the total dry weight of fish purchased by the Cooperative during the same period and obtained from the official receipts. An allowance was made for the small quantities of filleted-dried fish recorded (these require a conversion factor of 10 - see below) and the conversion factors summarised in Table 6.4. are for salted-dried fish only.

The Lowarengak value in Table 6.4 does not include the period November 1973 to February 1974 when lower conversion rates confirmed suspicions that the fish recorder was not recording all the fish. The values overlap those of Table 6.3 and also confirm the accuracy of the fish recorders' data, with the exception noted above. It is therefore recommended that a conversion factor of 2.8 (or ratio of 2.8:1) should be applied to weights of salted-dried fish purchased by the Cooperatives from the fishermen in order to obtain an accurate estimate of fresh weight. The small number of salted-dried Lates niloticus minus their heads will have a negligible effect on the overall conversions.

Following the advice of an FAO representative in the early 1960's, the Fisheries Department have been using conversion rates for Lake Turkana of 4 for salted-dried and smoked fish, 10 for dried fillets of Lates niloticus and 7 for dried fillets of other species. The value of 4 for salted-dried fish assumed a degree of drying much higher than is indicated by the above results. Since the fresh weight yields are normally calculated from the dried weights measured when purchased from the fishermen, then one would not expect values to be greater than the ranges indicated in Table 6.3.

The great majority of fish are salted-dried and, as a result of using the incorrect conversion factor, annual yields of the Lake Turkana fishery have been overestimated by 25-30%. Figure 6.3.1 shows estimates of annual yield using the new conversion rate together with the figures published in the Annual Reports of the Fisheries Department.

The author accepts the 10:1 ratio for dried-fillets of Lates niloticus, which was also used by MANN (1964), but has extended it to all filleted-dried products. The 4:1 ratio for whole, smoked fish is also accepted, since the heating process in the absence of salt ensures rapid dehydration of the product.

THE TRAFFIC OF FISH THROUGH COOPERATIVE BRANCHES

During the middle of 1972 the author recruited and trained Fish Recorders for full-time work paid by the Fisheries Department. They were required to identify the fish species, whether in salted-dried, filleted-dried or smoked form. The numbers of each species received from each fisherman were recorded on data sheets at the time of purchase and the numbers entered in the appropriate columns of the questionnaire or data sheet. Part of such a data sheet is shown in Figure 6.IV, Appendix 6.IV.

In the case of large Lates niloticus, a number of dried-fillets often represented a single fish. In such cases the Recorder asked the fisherman from what number of fish his fillets were obtained. Both number of fillets and fish were recorded as shown in Figure 6.IV.

Small Lates niloticus could not be distinguished readily from Lates longispinis in any processed form, and both were recorded as Lates spp. Estimates of the species composition of the catch are given later. All Sarotherodon and Tilapia were recorded as Tilapia although the great majority were actually Sarotherodon niloticus.

The Recorder at Kalokol Cooperative Branch completed separate sheets depending on whether the fisherman had been in the Namudak or Kalakol regions. This was aided by frequent visits to Namudak for fish purchasing by the Cooperative officials who were accompanied by the Recorder. From November 1973 onwards, the Recorder completed a third set of sheets for fish caught on the Eastern Shore and near Central Island.

The work of the Fish Recorders was personally checked monthly by the author and a good standard of work was obtained.

The numbers of each species were summed on a monthly and on a weekly basis and the monthly values are shown separately for each region in Tables 6.5 to 6.13. Values of more than 100 are shown to the nearest 10. Many important species show considerable month-to-month variation and this is discussed for different species in terms of catch per effort later in this Chapter. The monthly numbers shown in Tables 6.5 to 6.13 were converted into fresh weights using the monthly mean weight data given in Appendix 6.III. Monthly fresh weights were then summed to give the annual values for each species at each Cooperative shown in Table 6.14. Values for the early months of 1972, before the study commenced, were estimated from data collected in the second half of the year. Corrections derived from the differences between the initial and final months in subsequent years were employed to allow for seasonal changes in the 1972 catches. The total weight so obtained, after allowing for the filleted-dried portion, was within 2% of the fresh weight calculated from the salted-dried Cooperative data.

The recording at Eliye Cooperative was done voluntarily by the manager for a smaller period of time. The values for 1972 and 1974 shown in Table 6.14 were estimated by the author from limited data, and were influenced by trends shown in adjoining regions from major species.

A number of points should be considered in interpreting the results in Tables 6.5 to 6.14. Firstly, the numbers are considerably modified for some species when extra-Cooperative trade and subsistence is taken into account as shown in the following section. Secondly, the origin of some species is not always defined by the Cooperative Branch or "buying point". As noted earlier, many fishermen cross to the Eastern shore and fish off Central and North Islands. Some fish purchased at Nachukui (mainly the Bagrus bayad from long-lining) came from North Island. Similarly much of the Bagrus bayad recorded as coming from the Eastern Shore (through Kalokol Cooperative Branch, Table 6.8) was actually caught in deep water near Central Island.

During July to October 1973 inclusive, catches recorded under Kalakol (Table 6.7) included fish from the Eastern Shore. From November 1973 onwards, catches from the Eastern Shore were recorded separately as mentioned above, but it is apparent that there was some 'mixing' with fish from other areas (particularly Clarias lazera). It was suspected that some fish recorded at Lowarengak, particularly Heterotis niloticus, had been caught in the Todenyang region and this is supported by evidence showing the movement of fishermen between the two regions given in pages 364 to 366. Most fish recorded at Eliye originated from the Eastern Shore and the same applies to many fish sold at Kerio during 1974. The same points should be taken into consideration when inspecting the yield data (see pages 362-363).

Subsistence fishing and extra-cooperative trade

In all regions fish consumed locally for subsistence formed a small but significant part of the yield and, apart from Todenyang, Lowarengak and Nachukui, extra-cooperative trade was appreciable, particularly at Kalokol, at Namudak and on sections of the Eastern Shore serving Kalokol.

Subsistence fishing

The quantity of fish reserved by each fisherman for family consumption (i.e. for subsistence) was conveniently calculated from comparisons of catch per effort from experimental nets in the Todenyang area and from the Cooperative data as detailed on pages 376 to 379 . The difference in the values of mean catch per effort provides an estimate of subsistence rate since no extra cooperative trade was involved. It was calculated that 5.64 Kg of fresh fish per fisherman per week was accounted for by local consumption. In addition, proportions by weight of the species involved in subsistence over the five month period of observation could be estimated. Similar comparisons were made between catch per effort from experimental and cooperative data at Kalokol and Kerio and, since in these areas the species involved in extra-cooporative trade were known, proportions of species consumed locally (at the same rate per fisherman as at Todenyang) were estimated (see pages 376-377). Estimates of the proportion by weight of the species involved in subsistence are presented in Table 6.15.

The effects of decreasing mesh sizes (see page 1040)and the expansion of long-lining for *Bagrus bayad* in 1974 increased catches of all species listed in Table 6.15, but the proportions probably did not change appreciably between 1972 and 1974. In 1972 the relative quantities of these species may have been overestimated as other species were probably involved. The total subsistence rates for each year are based on the F values discussed on page 369. In areas where no data were collected on this topic, it is presumed that the proportions of different species involved in subsistence fall within the extremes shown in Table 6.15. The results in terms of fresh tons per annum are shown in Table 6.18, along with the extra-cooperative estimates outlined below.

Extra-cooperative trade

This was mostly in the form of smoked and filleted-dried products sold within Kenya by individual traders originating from outside the Lake Turkana region. Formerly most of the trade consisted of filleted-dried *Lates niloticus* and *Citharinus* with the latter declining to insignificance in 1972. From 1972 to 1974 filleted-dried *Lates niloticus* continued to be exported, but this product was gradually superceded by whole smoked fish produced in rapidly increasing quantities, using dum palm nuts as fuel. The species involved in the smoked trade were principally *Sarotherodon* spp., *Labeo*, *Synodontis schall* and small numbers of *Barbus bynni*.

Minimum estimates of the volume of the filleted-dried trade were obtained as a result of fishermen using facilities of the Kalakol Cooperative to check the weight of their catch before selling to traders. The weights were recorded. Minimum estimates of the volume of the smoked fish trade were obtained from records of a tax imposed on extra-cooperative exports from Kalokol, and the monthly fresh weight equivalents are shown in Table 6.16. Increases towards the end of 1974 were due to much smaller mesh sizes being used in the Kalokol area, and at the beginning of 1975 large numbers of immature (20-30 cm Sarotherodon niloticus) were being caught in Ferguson's Gulf due to unusually low mortality of the young during the previous year (HOPSON, pers. comm.).

A further estimate of extra-cooperative trade was made by comparing catch per effort from experimental nets (see page 377) with records of fish marketed during the same period from the Kalokol, Eastern Shore and Kerio cooperative regions, taking into account subsistence requirements. This estimate of extra-cooperative trade was found to be 23% more than the total estimates for smoked and filleted-dried products derived independently as described in the previous paragraph. The by-passing of Kalokol by extra-cooperative trade from Kerio accounts for only a small proportion of the difference. Other outlets, such as the marketing of fresh fish, were negligible and the difference was attributed to the fact that the estimates of the quantities of smoked and filleted-dried fish were both minimum. The 23% higher estimate of extra-cooperative trade derived from catch per effort comparisons was therefore adopted for calculations of total yield (see below).

The species composition of smoked fish was not accurately determined, but spot checks by the author in 1973 indicated the weight percentages shown in Table 6.17. Entries for the following year are more approximate estimates based on qualitative reports and decreasing mesh sizes.

Table 6.18 shows the breakdown of the estimates for subsistence and extra-cooperative trade for each species and region in terms of metric tons (fresh weight) per annum.

Total yields, regional yields, specific yields and yields per unit area

It was demonstrated (see page 359) that values of annual yield published previously in the Fisheries Department Annual Reports had been overestimated due to the use of an incorrect conversion factor for salted-dried products. Figure 6.3 shows the annual yields between 1963 and 1974, with the Annual Report values shown in dotted lines for comparison. These were concurrent with the author's estimates prior to 1966 since the salted-dried market only began during that year. The larger discrepancy in 1972 was due to the author's estimate of extra-cooperative exports being lower also.

Unfortunately there was no systematic sampling of species composition of the yields prior to 1972 and therefore only a broad picture can be given. From 1963 to 1965 the yield was mostly Sarotherodon spp. and Lates niloticus with smaller quantities of Clarias and Bagrus bayad. Beach seining supplemented by hand-lines, basket-trapping and harpooning accounted for most of the catches. From 1966, when the Zaire market was opened, 8 inch gillnets became the principal fishing gear and Citharinus dominated the catches. Less quantities of Distichodus were caught together with small numbers of Lates niloticus and large Silurids. From about 1971, a gradual increase in the use of smaller mesh nets resulted in the catches diversifying, with Labeo, Hydrocynus and Synodontis schall becoming more important.

These trends can be studied more accurately from 1972 to 1974 by reference to Table 6.19. Further diversification of species was by then as much due to fishing in new areas as the accelerating increase in smaller meshes. Probable explanations for yield trends are discussed under each species on pages 379 to 384 after effort and catch/effort have been explained and worked out in the following two sections.

Annual yield per unit area is a useful parameter for comparison with other fisheries and under certain conditions for the extrapolation of results within the same fishery. Table 6.20 shows the annual yield in tonnes per Km^2 per annum for 1972, 1973 and 1974 estimated for the different regions, and for the whole exploited area. For conversion to units of Kg per hectare per annum the values must be multiplied by ten. None of these values (Table 6.20) can be regarded as substainable yields because of instability due to the declining catches of previously underexploited species. If the Eastern Shore (through Kalokol) and Kalokol figures are not included for 1973 and 1974, total values of 3.10 and 2.86 are obtained respectively. Despite the facts that the exclusions still do not account for all the fishing in new areas after 1972, and that average mesh sizes have been decreasing, the values of 3.10 and 2.86 still represent successive reductions in yield per unit area. As shown later this decline cannot be explained by a change in overall fishing intensity.

On the basis of these observations it may be concluded that for the species and lake areas at present exploited, the mean annual sustainable yield is less than 2.86 tonnes/Km^2. The extrapolation of this figure to other areas of the lake would be inadvisable.

The economic value of the yield can be increased, however, and this has been occurring recently. A breakdown of yields for the last three years into fish products on a fresh weight basis is shown in Table 6.21. The filleted-dried figures include cooperative and extra-cooperative trade. Some important trends, particularly a marked increase in the higher value smoked fish are discernable.

The total value to the fishermen of fish exported during 1974 was approximately 1,910,000 Kenya shillings or Ksh 1,550 per 'full time fisherman' per year. It is estimated that each fisherman spends about Ksh 360 of his annual income on fishing gear (McCONNEL, pers. comm.). Details of fishing effort and gear are given below.

EFFORT IN THE COMMERCIAL FISHERY

Introduction

Several independent methods were used to assess the commercial effort and its constituent parts. Each method was based on a different category of information:

(a) Complete record of individual fishermen selling catches to Cooperative "buying points"

(b) Number of boats and rafts used on the Lake

(c) Average number of gillnets used per fisherman

(d) Average length and depth of gillnets

(e) Mesh sizes of gillnets used in different regions

Method (a) is described below and the following section (with Appendix IV.2) describes the computation of this measure of effort outside the calibration period. The section on Fishing Craft describes method (b), and the last three methods concerning net measurements are included in the subsequent section, along with general observations. Finally the merits of various combinations of the methods as measures of commercial fishing effort are discussed.

Record of Fishermen

In the course of a period of at least 15 weeks, between November 1973 and February 1974, the fish recorders entered the cooperative number and name of every fisherman selling his catch, along with the normal record of numbers of each species of fish purchased by the Cooperative. Each 'fishing family unit' (referred to as 'fisherman' for convenience) possessed a number along with their name normally carved on a small wooden plaque. The number is used by the Cooperative, being copied down on the receipt given to the fisherman which can then be cashed. The author would have used the copy receipt books but for the fact that different fishermen have been allowed to use identical numbers. Hence the necessity for copying down the name alongside the number of each 'fisherman'. The possibility of two or more fishermen having the same number and name is considered remote.

Every visit by a 'fisherman' had to be recorded (the recorders knew that visits could be checked in the receipt books), even when the same 'fisherman' returned the same day. The value of the catch is only accurately known when fish is weighed and sold. Since an outsider would not be trusted to handle an unknown amount of cash, it is the usual practice for 'fishermen' to trade at the cooperative only with fish caught by their own family.

Thus an inventory of fishermen was made up consisting of a card for each 'fisherman' containing the name, number and record of visits for every week of the recording period. This process, involving the indexing of over 30,000 visits, was completed for Todenyang, Lowarengak, Kerio, Namudak, Kalokol (only) and East Coast (through Kalokol). In addition, data from Kalokol Cooperative Branch as a whole were analysed as a check of the recorder's ability to verify the origin of fishermen and their catches arriving from Namudak, East Coast (through Kalokol) and Kalokol (only). Kataboi and Nachukui were analysed as explained in Appendix 6.IV.1.

All the cards were re-sorted in alphabetical order to be checked for errors in the copying of numbers by the recorders. Due to this cross-checking system, most errors were obvious, and those which required a subjective assessment amounted to less than 2% in terms of the number of fishermen per week.

The week was the most convenient time interval for summing and calibration of the results. A calculator program summed the results from the cards, which are defined below:

F_{tot} = Total number of different 'fishermen' visiting Cooperative Branch over whole period

V = Total number of visits of fishermen during each week

F = Total number of different 'fishermen' visiting each week ≃ total 'commercially active fishermen' per week.

'F_{tot}' for a given region represents the total pool of 'fishermen' fishing commercially at some time in the area during the period recorded. It is not an estimate of the fishing effort, because many fishermen only work part time, often tending livestock or cultivating sorghum plots and sometimes only fishing for subsistence.

'V' also does not give an estimate of fishing effort, but is related to it as described in Appendix 6.IV.1.

'F' provides the best estimate of catch per effort in terms of commercial catch per fisherman per week when combined with the calculated fresh weight purchased by the Cooperative Branch for the same week. 'F' does not represent the total number of 'commercially active fishermen' per week, but its value will be close since those catching no fish, or those not selling their dried catch for an entire week are very few, if any. Because of the need for a steady, if small, cash supply, a member of the 'fishing family unit', normally a wife, is continuously transporting even small catches to the nearest 'buying point' as soon as they are dried.

Table 6.22 shows the values of F for each of the weeks calibrated in each fishing region, starting with the week beginning 12th November 1973.

The 'F' values for Kalokol Cooperative Branch as a whole were analysed separately, so that the degree of separation between the three fishing areas: Namudak, East Coast (through Kalokol) and Kalokol (only) could be assessed. These values are shown in Table 6.23 with the sums of the respective regions from Table 6.22 for comparison and with their differences expressed as percentage overlap.

It is apparent from Table 6.23 that the same 'fisherman' is reported as having brought in fish from more than one area in the same week. This may be explained by the family being split, with the man making the arduous crossing to the eastern shore, whilst other members are fishing closer to home. Also, as explained below, rougher weather can change the fishing pattern in the course of a week. The overlap may also be due to difficulty on the part of the recorder of always ascertaining the correct region fished by each fisherman. There is evidence in the species composition of catches shown in Chapter 3 that some mixing has occurred.

Despite these factors, the percentage overlap is considered low enough for the areas to be treated separately, and the errors involved are minor compared with the assessment of catches sold outside Kalokol Cooperative, as indicated in the next section.

Finally, in Table 6.24 the 'F_{tot}' values are compared with the means of the 'F' values (F) from Tables 6.22 and 6.23. F is also shown as a percentage of the respective pool of fishermen, F_{tot}.

The values relating to the Kalokol Cooperative are relatively lower, showing the large degree of movement of fishermen within the three regions serving that branch. One reason for this is that when the water is rougher, less fishermen risk the crossing to the eastern shore and fish at Kalokol or Namudak instead. Apart from regions serving Kalokol, the values are very consistent, and as mentioned previously they are considered to be mainly influenced by the degree of deployment in activities other than commercial fishing. Only a small degree of variation is attributable to migration from one Cooperative Branch to another during the recording period. This was known to occur most frequently between Todenyang and Lowarengak and was therefore measured using the index card records. 80 fishermen normally selling in Todenyang, sold in Lowarengak, and 4 vice versa over the 15 weeks. Therefore, of the total pool of 1,508 fishermen (Table 6.24) only 84 moved from one cooperative to the other. Obviously over a longer period of time the number migrating would increase, but so would the F_{tot} values, a dependency which again rules out the use of F_{tot} as a measure of fishing effort.

The only 'buying point' not recorded was Eliye, which was reported by the manager to have an average of 40 fishermen using the 4 boats. Assuming the pool of fishermen, F_{tot} at Eliye to be 70, summing the other values of F_{tot} and allowing for migration, the total number of 'fishing family units' at some time commercially active during the fifteen weeks was about 2,870.

Over a longer period of time, this figure would undoubtedly increase, but many only fish for a while and then return to their traditional nomadic-pastoral life.

A measure of total commercial fishing effort can be estimated by summing the 'F' values for the different areas to give total 'commercially active fishermen' per week after allowing for the overlap shown in Table 6.23. Over the calibration period this averaged 1,330 with a standard deviation of 150.

As indicated earlier, a large proportion of the catches from some regions were involved in the extra-cooperative trade. It was presumed that 'F' values included those fishermen which were also engaged in this trade. This was a reasonable assumption since the number of species involved was limited, and it would have been unlikely for fishermen to operate gillnets, seine nets or long-lines for an entire week without catching species which were acceptable only to the Cooperative. This same assumption was applied to the catch per effort comparisons (see pages 376 to 379).

Estimations of 'commercial fishing effort' outside the calibration period and of 'total fishing effort'

The methods of recording allowed systems of calibration to be worked out for all of the Cooperative Branches, in order that 'F' could be estimated with sufficient accuracy for weeks outside the recording period referred to in the preceding section. The methods employed are described in Appendix 6.IV.2.

From the middle of 1972 until the end of 1974 weekly commercial fishing effort in terms of 'F' was calculated for all major buying points. Table 6.25 shows the mean 'F' values for each year (or part of year in the case of 1972) with the maximum 'F' value within each annual period, defined as F_{max}. The figures for Eliye are less accurate, being based on number of boats (see page 355) and on reports from the Cooperative Manager. The values for Kalokol (only) and

Eastern Shore (through Kalokol) in 1973 are based on fewer weeks because, for a period, records from the two regions had not yet been separated, and fishing from those areas of the eastern shore serving Kalokol did not commence at the beginning of the year.

Inspection of the $\bar{F}$ values in Table 6.25 reveals some important trends in the distribution of commercial fishing effort which confirm quantitatively the general observations noted early in this chapter. At Todenyang a twofold increase between 1972 and 1973 was followed by a slight decrease between 1973 and 1974. At Lowarengak $\bar{F}$ also increased initially before levelling off while at Nachukui and Kataboi commercial effort remained stable. Steady decreases at Namudak and Kalokol from the middle of 1973 onwards were probably largely due to the attraction of fishing on the eastern shore. Values of $\bar{F}$ at Kerio declined steadily, confirming reports from the local mission (Father O'CARROL, pers. comm.) that from 1973 onwards many fishermen left the industry having made enough money to replenish their herds and return to a pastoral life.

In general, F_{max} values showed similar trends, and $\bar{F}$ expressed as a percentage of F_{max} was fairly constant, averaging 65.0% with a standard deviation of 8.3. F_{max} can be regarded as the most successful fishing week when all the fishermen were commercially active. During other weeks it is presumed that (F_{max} - F) fishermen are subsistence fishing only. Therefore over the year it is presumed that F_{max} fishermen account for the subsistence rate calculated on page 365 and $\bar{F}$ (the mean of commercial active fishermen per week) accounts for the commercial fish catches. An exception to this hypothesis is made for the Eastern Shore supplying Kalokol, since all fishermen from there can be expected to catch in excess of subsistence requirements. F_{max} should not be confused with the larger F_{tot} which is a measure of the turnover of fishermen and, as explained in the preceding section, depends on the time period of calibration.

The total fishing effort for each region therefore consists of $\bar{F}$ plus an amount equivalent to the average fishing effort of those only catching enough for subsistence. This latter amount cannot be (F_{max} - $\bar{F}$) as this would assume the efficiency of 'subsistence only' fishermen to be the same as 'commercial plus subsistence' fishermen. From comparisons of the subsistence rate with the total mean catch per effort of the commercially active fishermen in each region, the relative efficiency, 's' of 'subsistence only fishermen' (≡F_{max} - $\bar{F}$) was found to be between 11% and 13%. The total fishing effort, 'E', is therefore defined as $\bar{F}$ + s (F_{max} - $\bar{F}$).The units of 'E' may be defined as "the equivalent number of full-time fishermen over a certain time period". The power of these fishermen in terms of numbers of nets is discussed later.

Table 6.26 summarizes the values of E which are then used for the calculation of mean annual catch per effort (see page 371). The small overlap of regions supplying the Kalokol Branch discussed earlier is allowed for in the total values. A comparison of the results in Tables 6.25 and 6.26 shows that the values of E are higher than the values of $\bar{F}$ by a small, fairly constant proportion. Consequently, $\bar{F}$ is a suitable substitute for E in week to week comparisons of the catches of commercial fish species.

The total estimates of E for the entire fishery (Table 6.26) indicate a 17% increase from 1972 to 1973 and a 4% decrease from 1973 to 1974. The overall fishing intensity, using the approximate estimates of areas regularly fished given in Table 6.20, shows a slight decrease (Table 6.26). The regional distribution of fishing intensity (Table 6.26) altered considerably over the study period and there were also notable changes in fishing gear as will be discussed below.

FISHING CRAFT

Most of the craft in use on Lake Turkana were Sesse type canoes, about 7 metres in length and constructed of wood or fibreglass. There were also lesser numbers of dinghies made of wood, fibreglass or metal and a few Merille dug-out canoes were still operational. The traditional rafts, made of four or five dum palm logs tied together, were still in regular use for fishing closer to the shore.

Two surveys were undertaken to count the boats, during the second of which the number of rafts was also recorded. The first survey was made by boat off the west shore in April 1972, travelling northwards from Kalokol. The second was an aerial count along the same route on 1st October 1973. In both cases the counts were supplemented by information from the shore for other regions.

The aerial count was effected by two workers counting boats and rafts on each side of the aircraft, the pilot being instructed not to fly directly over craft. This combined count was checked on the return trip, and the two results differed by 1 boat (<1%) and 8 rafts (≤10%). The seven upturned boats counted were later found to be derelict and were omitted from the counts. The larger discrepancy in the raft counts was due to difficulties in observing them beached on the shore. A mean of 88 rafts was estimated. Most of these were between Kalokol and Kataboi, with many in the Kataboi region. The raft fishing made only a small contribution to the commercial fishery and was largely concerned with subsistence.

The boat counts and distributions from the two surveys, with supplementary information from Eliye and Kerio, are shown in Table 6.27. This table indicates an increase in fishing activity in three areas: Todenyang, the Eastern Shore and Kerio.

Presuming that the rafts were used by a negligible number of the 'commercially active fishermen' (F), the overall value of F per boat lies between 11 and 12. Direct, field surveys of individual boats at Kalokol and Kataboi indicated respective averages of 10 and 11 fishermen using the boats. This does not mean that the boats always contained the full complement, since they were normally used on a shift basis and usually contained less than half this number of fishermen at a time. There may in fact have been more than the average per boat quoted above because a proportion of fishermen in any week may not have been 'commercial active'.

From the middle of 1973, fishermen from outside the Turkana district began fishing in addition to the fish trading carried on earlier, and a few boats, including some with outboard motors were used.

COMMERCIAL NET MEASUREMENT AND GILLNETTING METHODS

Several important factors relating to gear were measured as extensively as possible:

(a) numbers of gillnets used per fisherman

(b) average length and depth of the nets

(c) stretched mesh sizes

Numbers of nets were observed from the air, but conditions did not allow accurate counts to be made. The count of nets made during a survey by boat in April 1972 undoubtedly missed a large number of the nets set in the lake. The numbers of nets observed in returning boats gave no indication of how many nets were in use on the fishing grounds.

The best practicable method for counting nets was to deploy a fish scout known personally by the fishermen to use a questionnaire and determine the number of nets used by each head of family. The scout understood that there was often a difference between the number of nets owned and the number normally being fished. The latter is a component of fishing effort and was the measurement required. Table 6.28 summarizes the results of this survey of fishermen using boats.

A further component of fishing effort is the length and depth of the nets when hung. Most of the new nets sold by the Cooperative were 45.7 m (50 yards) long by about 3.7 m (4 yards) deep when hung by the half (i.e. with 50% slack). However, the nets were often shortened in the course of mending after damage, and many were made locally with smaller dimensions. Measurements of a total of 39 nets at Todenyang and Kalokol indicated a mean length of 30 m (33 yards) and depth of 2.7 m (3 yards). A number of nets at Kerio were hung from stakes driven into the bottom in shallow water, and their mean length was only 16.5 m (18 yards) from a sample of 13.

Data on mesh size distribution is essential both in providing an accurate assessment of fishing effort and for the study of species selectivity discussed below. It was found that after an exceptionally windy period of a few days, large numbers of nets were recovered for sorting out and mending on the shore, and this was the best time for representative samples to be measured. Since the mesh sizes of purchased nets and also the experimental nets (see page 619) were in inches, the commercial nets were measured accordingly. The mean of 5 measurements of the stretched mesh between the knot centres (twice the 'bar' size) was calculated and recorded to the nearest ¼" (about 0.6 cm). Table 6.29 shows the results and dates of measurements of all the nets measured in 1973 and at the beginning of 1975. The numbers of nets in ½-inch intervals are expressed as percentages to facilitate comparisons.

Figure 6.23 summarizes the results in graphical form, and shows differences in distributions between regions measured at similar times, and changes in distribution between 1973 and early 1975. These important changes will be discussed later in relation to the species composition of catches and the interpretation of catch per effort data.

The bimodal character of some of the distributions (see Fig 6.4) is due to a changeover from large mesh sizes of 7 inches and above to small mesh sizes of under 5 inches during the study period. It was observed in early 1974 that 7½" and 8" nets still being sold in the Cooperative branches were being taken apart in order to make smaller mesh nets. This was cheaper than buying the twine direct.

At Kerio the shorter than average nets set from stakes (see above) tended to be of relatively small mesh size compared with nets of normal length set from boats. An allowance was made for their shorter length in the preparation of mesh size frequency distributions. Despite this correction, Kerio results for 1973 contain a much larger proportion of smaller nets than was observed in other regions during this period.

General observations of the commercial nets indicated an almost universal use of white or light fawn multifilament nylon, and only two nets (0.5%) were of monofilament nylon. Ply ratings were similar or slightly heavier than the experimental nets described in the next main section. Almost all were hung by the half from ropes of natural fibre using polystyrene or cork floats, and stones for weighting. The large end-floats were almost invariably dum palm logs.

Most of the nets were bottom set, with numbers belonging to different fishermen joined together to increase their effectiveness. The fleets, usually set at right-angles to the shore, were often 250-300 m long. Nets seen at the surface were mainly in shallow water and thus reached the bottom; surface-set nets were uncommon, although in previous years they were regularly used to catch Citharinus citharus which was formerly abundant.

Discussion and conclusions

The main purpose of the counts and measurements described above was to monitor the commercial fishing effort, to relate it to the catches, and to compare it with experimental gill-netting described in the next section.

The use of the boat as a unit of fishing effort presented numerous difficulties. The relative efficiency of fishing craft varied considerably and depended both on design and on the state of repair. No practicable way of monitoring the movements of boats from one area to another was available. The contribution made by rafts in some areas may have been appreciable. At Kerio a significant proportion of the nets were set without the aid of fishing craft by fishermen wading far offshore in shallow water.

The factor F as described earlier (see page 365) was a more satisfactory unit of fishing effort, and could be calculated weekly for each region from the recorder's data as demonstrated (see page 379). Nets are left in position on the fishing grounds almost continually and visited at least once daily for the removal of fish. During calm the nets may be examined soon after dawn and again later in the day but persistently high winds may at times prevent the lifting of the gear for two or three days. An analysis of 77 settings at Todenyang showed that on average, nets were lifted slightly more than once per day. (Table 6.46).

In order to compare the commercial fishery catch per effort with that of the experimental nets the factors previously discussed on pages 356 to 359 were employed in conjunction with F (see next section for results). As mentioned previously, gillnets are not universally used by Turkana fishermen and in some areas long-lining and beach-seining make important contributions to the commercial catch. For this reason, catch per effort is expressed as 'commercial catch (kg) per fisherman per week' rather than in terms of catch per net.

The 'total fishing effort', E, is considered more accurate than F for calculating mean catch per efffort from annual yields and is used in the following section.

THE ESTIMATION OF CATCH PER EFFORT FROM COMMERCIAL FISHERY STATISTICS AND FROM EXPERIMENTAL GILLNET DATA

Introduction

It is impossible to make a thorough appraisal of a fishery without reliable information on catch per effort. Such data often provides the only means by which fluctuations in fish abundance can be monitored. Changes in the relative abundance of certain species over the study period are easily detected in the annual catch per effort figures discussed in the next section.

One section describes inshore experimental gillnetting and analyses the effect of certain important factors on catch per effort and on species selection.

In another section catch per effort records from the experimental nets are compared with corresponding figures derived from the fish recorder's data for the various regions.

A further section compares past values of catch per effort with those obtained in 1973 and 1974.

Finally, weekly values of commercial catch per effort for the major species are presented.

Catch per effort for annual yields

Using the estimates of annual yield shown in Table 6.19 and the corresponding values of total effort (E) from Table 6.26, catch per effort was calculated for each species, region and year. The results (Table 6.30) are expressed in units of fresh kg per full-time fisherman per week,

$$\text{i.e. catch per effort} = \frac{Y \times 1000}{E \times 52}$$

where Y = yield, metric tons/annum,
and E = mean effort (mean number full time fishermen per week; see page 367).

The accuracy of the estimates (Table 6.30) varies, and comments made previously on extra-cooperative trade, etc. are taken into account when the species concerned are discussed later (see page 377).

Care is required in drawing conclusions from Table 6.30 because the values are influenced not only by changes in stock densities but also to a varying degree by the reduction in gillnet mesh sizes, by the use of more long-lines and by the redistribution of fishing intensity, particularly by expansion into previously unexploited areas. Since gillnets accounted for most species and about 90% of the yield, an understanding of the catch per effort and species selectivities of different mesh sizes is necessary, and an analysis of these factors is presented in the remaining sections of this chapter.

Experimental inshore gillnetting

(a) Gillnet specifications

The white, multifilament nylon nets were 91 m (100 yards) long and apprxomately 4 m (4.4 yards) deep when mounted. All were mounted by the half on 1.9 cm ($\frac{3}{4}$ inch) circ. headrope and 1.27 cm ($\frac{1}{2}$ inch) circ. footrope with headline to give a loading of 140 g/m. Other specifications are summarized in Table 6.31.

(b) Sampling Programme

Five areas were sampled, three of these being areas already exploited to some degree by the commercial fishery. Details are summarized in Table 6.32.

The program was restricted largely by the lack of trained and reliable gillnetting assistants. The Kerio and Todenyang (inshore) programs were carried out by local schools under the supervision of the headmasters, Father O'CARROL and Mr MUGANGE respectively, who in turn were regularly visited to check on results and on the condition of the experimental nets. The schools used their own boats, and the fish caught provided food for pupils and staff. Valuable information was collected and results compare well with estimates of commercial catch per effort (see page 371).

When assessing the following results, a number of points should be tken into consideration. A fact which could not have been easily foreseen was that the twine ratings of the smaller nets were too fine. Constant damage by crocodiles, soft-shelled turtles, large *Lates niloticus*, and *Synodontis schall* made it impossible to keep a full fleet operational. The nets were too long to be manageable in a complete fleet, and were later reduced to a length of 45.7 m (50 yards).

(c) Catch per effort: definition and results

The time interval between setting and hauling nets varied considerably and was influenced particularly by the prevailing wind pattern. The results were, therefore, analysed to decide whether catch per effort should be expressed as catch per setting (i.e. total catch removed from the net at the end of a fishing period) or as catch per time.

Data from 25 fishing periods (some of which had occurred consecutively during a single day) were analysed. These observations involved a total of 204 separate net settings at Todenyang and at Koobi Fora. The analyses proved that there was no correlation between catch per set and duration of set in any period. This apparent failure of fish to accumulate steadily in the nets with time may have been due to fright reaction to the presence of fish already enmeshed. Predation of soft-shelled turtle from the nets may have contributed considerably to such loss in certain areas. In 14 out of the 25 fishing periods investigated the variance of the catch per 24 hours was significantly greater ($P < 0.05$) than the variance of catch per set. No significant difference was noted in the remaining 11 periods. On the basis of these observations, all values of catch per effort for gillnets have been expressed as catch (kg of fresh fish) per setting of a standard net which is defined as 45.7 m (50 yds) long by 4 m (4.4 yds) deep when mounted.

Tables 6.33 to 6.37 show monthly mean catch per effort for the various mesh sizes in each sampling area. Data from all months have been combined to give the unweighted means for each area presented in Table 6.38.

MANN (1964) working in the Ferguson's Gulf area set a graded fleet of nine gillnets ranging from 2 inches to 6 inches stretched mesh. He recorded catches from a single 24 hour period. These results yield a 't' pair value of 1.31, indicating no significant difference between day and night catches.

(e) The effects of wind on catch per effort

Local fishermen consider that both very rough and calm conditions result in reduced catches.

Observations were made during the eight settings of the gillnet fleet at Koobi Fora, and by Mr Mugange at Todenyang.

At both stations wind speed was arbitrarily rated as follows:

0 = no wind, calm water;
1 = normal wind, rough water;
2 = very strong wind, very rough water.

At Koobi Fora the predominant condition was recorded separately for both the daylight and dark periods of each setting, whereas at Todenyang an estimate was made of prevalent conditions for the whole duration of each setting.

Data for the separate mesh sizes were too limited at Koobi Fora to reveal any significant differences associated with wind, and results were combined after reducing all the catch per effort values to standard measure. This involved dividing each catch per effort value by the mean value of the particular mesh size for the eight settings. Table 6.39 shows these values for each mesh size arranged according to wind rating. In the lower part of Table 6.39 results have been combined from all mesh sizes to give a mean value for four different wind ratings covering the range calm to very strong.

Inspection of Tables 6.39 and 6.40 reveals that the mean catch per effort in calm conditions appears to be less than in windy or very strong conditions. From the summary in Table 6.39 differences between rating '0' and ratings '2' and '3' are readily apparent. The high variance for rating '1' is due to a 55 kg specimen of Lates niloticus caught in the 9 inch net.

The catch per effort means for different mesh sizes in Table 6.40 suggest lower values during calm weather, in particular when compared in standard measure. The catch per effort distributions (including those in standard measure) are positively skewed and statistical tests are not valid without transformations to normalize them. This subject will be dealt with in a separate publication.

Although the subjective method of rating the wind may have prevented possible differences between 'windy' and 'very windy' conditions being detected, the difference between windy and calm conditions at Lake Turkana is obvious. The fact that both the Todenyang and Koobi Fora data indicate that relatively low catches are associated with calm weather would appear to be very significant.

Other important factors, such as river flow, rainfall and migrations affecting the catch per effort of particular species, are summarized later (see page 379).

(f) Species selection in relation to mesh size

Values of catch per effort may be misleading when commercial gear is changing to the extent that the species composition of the catches is altered.

Two aspects of the selection characteristics of gillnets in Lake Turkana are shown here. Fistly, the mean catch per effort of individual species for each mesh size was calculated for the various regions in terms of weight and numbers. These values are shown in Tables 6.41 to 6.44. Secondly, all the length frequencies of the different species caught in various mesh sizes have been accumulated (including data collected from 27 fleet settings during 1974, see Chapter 8, Table 8.) and are presented in Appendix 6.V. In Appendix 6.V.11 these data are summarized in terms of mean retention lengths for each mesh size. The mean retention lengths and the standard deviations shown in Appendix 6.V.11 represent the selective properties of the net in relation to a fish population of random size distribution, the individuals of which are all equally available for capture. Such a situation rarely occurs in nature and, in order to estimate selectivities Holt's method (HOLT, 1963) of comparing catches of pairs of closely similar mesh sizes was employed where this was possible. This assumed that the selection curves are approximately normal with similar standard deviations and that the fishing power of the pair of nets is the same. The validity of these assumptions for each species is discussed later. The frequencies shown in Appendix 6.V were combined into larger length units and corrected for the different number of standard net-sets (i.e. fishing effort) for each mesh. The log ratios of these values mostly gave good linear regressions with the mean lengths; and the resulting 'sums of mean selection lengths' are listed in Table 6.45 and plotted in Figure 6.5a against 'sums of mesh sizes'. These points (shown as '+' in Fig. 6.5a) suggest proportionality between calculated mean selection length and mesh size and the linear regression lines through the origin are shown in Figure 6.5a. In addition, the 'mean retention lengths' from Appendix 6.V.11 are plotted on the same graphs for comparison. In all cases these can be seen to depart from the calculated selection regressions above certain mesh sizes. This is due to low numbers (or in some cases to the non-existence) of fishes of lengths for which the larger mesh sizes are most efficient. The fact that some fish are caught at all in larger meshes is an indication of the relatively high standard deviations of the selection curves. Estimates of these, calculated from Holt's equation, are shown in Table 6.45.

The most consistent results were obtained from the data for Labeo and Hydrocynus. This is probably due to their isometric growth pattern (see Appendix 6.II.1) and body shape. With the exception of a small number of Hydrocynus enmeshed by their teeth, all examples of the two species were caught between the pectoral girdle and the origin of the dorsal fin where variations in body circumference are relatively small. An important departure from the hypothetical ideal situation, where the selection curve for each mesh size is identical in form, appears in both these species with standard deviations (Table 6.45) showing a significant tendency (correlation coefficient r = 0.93

and 0.94) to increase with mesh size. This is probably due mainly to a higher variance of condition factors in the mature fish. It is also in accordance with Holt's suggestion (HOLT, 1963, p111) that gillnet selection curves would be expected to be log-normal. In fact the data for some of the smaller meshes shown in Appendices 6.V.1 and 6.V.4 indicate slight positive skewness, suggesting log-normal curves when transformed. Larger samples might have warranted such a refinement in the analysis.

Barbus bynni and Distichodus both show allometric growth (Appendix 6.II.1) with weight tending to increase more rapidly than length cubed so that the girth is relatively greater in larger fish. With such tendencies, relatively smaller mean selection lengths would be expected for larger fish. In fact the points for the mesh pairs in the case of Barbus bynni (see Fig. 6.5a) suggest such a deviation from proportionality. Sexual differences could also account for this non-proportionality. However, it is considered that the data does not warrant a more detailed analysis, and the errors involved in presuming a proportional relationship for Barbus bynni are small. The significant correlations of three of the five pairs analysed for Distichodus indicate that the presumption of proportional relationship is adequate for the data available. In both these species standard deviations (Table 6.45) showed no significant tendency to increase or decrease with mesh size. Data for Barbus bynni (Appendix 6.V.5) suggest normal selection curves for smaller mesh sizes.

The two species of Lates are very similar morphologically but L. niloticus tends to be heavier for a given weight, as indicated by the length-weight expressions shown in Appendix 6.II.1. This difference is reflected in the mesh selectivity data where the length of L. niloticus caught in a given mesh size tends to be smaller than L. longispinis caught in the same net. HOPSON (1968a) working on L. niloticus from Lake Chad found relatively lower lengths for weight than was observed during the present study ($a_0 = 1.25 \times 10^{-2}$ for Lake Chad cf. 1.32×10^{-2} for Lake Turkana; see Appendix 6.II.1). A regression of mean retention lengths through zero for Lake Chad data gives a regression coefficient of 10.6, higher than the value of 10.1 obtained for the Lake Turkana population of L. niloticus (Table 6.45). There is apparently no significant positive correlation of standard deviation with mesh size in Lates and results for L. longispinis even suggest a decrease (Table 6.45). More selection data for L. longispinis in the 2, 3 and 4 inch nets would be useful to confirm or correct these indications. Length frequencies of Lates selected by a gillnet of given mesh size are probably not normally distributed due to the tendency of fish to be caught by the maxillaries and opercular spines as well as round the body. Lake Chad data (HOPSON, 1968a) show strong positive skewedness.

Most Synodontis schall were caught in the gillnets by tangling and selectivity data diverge from the normal pattern. Despite this, a slight increase in mean retention length is discernable with increasing mesh size in the smaller nets and large samples enabled analyses to be conducted on the two smallest mesh pairs. The results indicate a linear relationship between theoretical mean selection length and mesh size in nets up to 4 inch mesh. With larger mesh sizes the theoretical mean selection length is greater than the maximum size of the fish and all are then caught by tangling. Most Bagrus bayad were caught by tangling but data were too limited for detailed analysis.

Table 6.45 also shows values of 'mean coefficient of variation' which is the mean of the standard deviation divided by the 'equivalent mean selection length'. This procedure provides comparable relative standard deviations and as expected, the lowest values occurred in Labeo and Hydrocynus, and the highest in Synodontis schall. Among species with intermediate values, Distichodus is relatively high because of the combination of a deep body and rough scales, which would tend to increase the length range liable for capture in a particular mesh size.

Citharinus appeared in the nets over such a limited length range that Holt's method was impracticable. However, the regression coefficient of mean selection length/mesh size estimated from the mean retention lengths was 7.8 cm (TL)/mesh size (inches), which compares with 7.6 calculated from Lake Mobutu (formerly Lake Albert) data from 5, 7 and 9 inch nets (WORTHINGTON, 1929) and 6.8 calculated from Lake Chad data from 6 and 7.5 inch nets (HOPSON, 1968a), for the same species and corrected to the same units. These regression coefficients cannot be regarded as more than rough guides since they were derived from mean retention lengths. A standard deviation of 12 cm is estimated for the length frequencies of Citharinus caught in 6 inch nets.

The above results concerning the selectivity of gillnets and the distribution of species by weight and numbers among different mesh sizes are vital to an understanding of recent trends in the species composition of the fishery and of the control of exploitation by mesh size limitation. Results for particular species are discussed in the next main section (see page 379). The data are incomplete since certain species such as Alestes baremose and Schilbe uranoscopus which do not at present occur commonly in Lake Turkana catches become important if mesh sizes in the commercial fishery continue to fall.

Comparisons of experimental and commercial catch per effort

It was necessary firstly to compare the independently obtained values of catch per effort from experimental gillnets with the commercial catch in an area where all fish in excess of subsistence needs were sold to the Cooperative, and where practically the entire catch was obtained by gillnets. Todenyang satisfied these conditions, and provided concurrent data for a period of over 4 months in 1973. In order to compare these data the following information was utilized.

The average fishing power of the commercial fishermen was taken into account. The section on commercial net measurement and gillnetting methods (see page 365) provides the relevant data in the form of mean number of nets per fisherman (2.65 from Table 6.28) and mean size of the nets (30 m long by 2.7 m deep when hung). Ignoring the small difference in depth, this is equivalent to 1.75 standard nets (45.7 m) per fisherman (or a total length of 80 m per fisherman).

Commercial catch per effort is expressed in terms of total weekly fresh weight (in kg.) per commercially active fisherman (F). Experimental catches for each mesh size were grouped into equivalent weeks with an allowance for a drying period of five days between the capture and marketing of commercial fish. These data, for mesh sizes ranging from 5 to 8 inches (Table 6.36) were used in combination with commercial mesh size frequency distribution data for 14th March and 13th September 1973 (Table 6.29) to provide estimates of weekly commercial catches. The calculations included corrections to compensate for the proportion of each mesh size used in the commercial fishery. During weeks of incomplete experimental gillnetting, the value for the whole week was calculated by assuming one set per day (which was the average for the whole period) for the remaining days. After correcting for the fishing power described above (i.e. 1.75 standard nets per fisherman), the total catch per effort obtained was equivalent in units to the commercial catch per effort defined above.

The results are summarized in Table 6.46. The 17 pairs of values in the last two columns show a significant (r = 0.534 at 15 degrees of freedom) but not very close correlation, and the mean of the experimental results, as would be expected, exceeds that of the cooperative results. The difference of 5.64 kg per fisherman per week provides an estimate of the amount consumed locally (defined as 'subsistence rate') of each fisherman plus family.

The experimental fishing can be regarded as a subsample of the much more comprehensive commercial sample plus the small amount due to subsistence. It is important to note that the coefficient of variation of the series of values of the former is 40.3% compared with only 23.8% for the Cooperative results. Similar differences were also found with the comparisons in other regions outlined below, and reflect the more comprehensive 'sampling' of the commercial fishermen.

A comparison of the species composition of the catches over the period is shown in Table 6.47, using the same conversion methods outlined above. The first five species listed are preferred for salting and drying, and in fact their combined values of catch per effort values are 32.4 kg/F/week for both the Cooperative and experimental gillnet data. The fact that they add up to exactly the same figure is probably fortuitous in view of the difficulty of accurately sampling the less widely dispersed species. The 'other' species purchased by the Cooperative, mainly *Gymnarchus*, *Heterobranchus* and *Heterotis*, were too localized to appear in the experimental nets.

The combined catch per effort by *Hydrocynus*, *Bagrus bayad*, *Synodontis schall* and *Clarias* in the experimental nets amounted to 8.1 kg/F/week compared with only 2.0 kg in the cooperative results. The difference of 6.1 kg compares favourably with the estimated subsistence rate of 5.64 kg/F/week (see above). It seems likely that the four species concerned contribute to subsistence at Todenyang in proportions indicated by the difference between cooperative and experimental figures in Table 6.47.

A similar comparative analysis was made for Kerio, where concurrent data were obtained over 20 weeks. The correlation of the paired results was not significant, which is probably due to other types of gear being in use (see below). However, the mean values for the experimental and Cooperative catch per effort were 49.5 and 42 kg/F/week respectively, producing a difference of 7.5 which is attributed to subsistence and a small amount of extra-cooperative trade. The break-down of the values into a specific catch per effort for various species is shown in Table 6.48. The large difference in the values for *Sarotherodon* spp. was due to the fact that seine netting and some basket-trapping in localized areas accounted for practically all these species at Kerio. *Heterotis*, as at Todenyang, did not appear in the experimental nets, and similarly *Clarias* was underestimated.

However, the remaining species (other than Labeo) show reasonable concordance. Subsistence was accounted for partly by Bagrus bayad and Synodontis schall, as indicated by the differences between the two sets of results in Table 6.48, and partly by Labeo horie (see Table 6.15). Extra-cooperative trade from gillnets consisted chiefly of Labeo although some Sarotherodon was also marketed in this way (page 361).

A similar analysis was carried out for Kalokol where 4 weeks of concurrent data in January, February and May 1973 could be compared (Table 6.49). A good correlation was obtained (r = 0.974, 2 deg. F), but there were larger differences in the values due to more extra-cooperative trade. The means of the experimental and cooperative catch per effort values were 39.5 and 24.9 kg/F/week respectively, and the difference of 14.6 kg is accounted for by subsistence and extra-cooperative trade. If it is assumed that the subsistence rate was similar to that estimated for Todenyang, it would appear that at Kalokol about 26% of the total commercial catch is marketed outside the Cooperative. This proportion increased substantially during 1974. The experimental nets at Kalokol failed to catch any Distichodus which were probably distributed in slightly deeper water than the sampling area (Table 6.49). Hydrocynus and Synodontis schall together probably account for most of the fish removed for subsistence. Prior to 1973, most of the extra-cooperative trade at Kalokol was accounted for by dried-filleted Lates niloticus as mentioned on page 361 . Later smoked Labeo increased in importance. The difference in the Citharinus values was probably due to sampling error, as there was no evidence to show that this species was involved in extra-cooperative trade from 1972 onwards. Also included are estimates of Sarotherodon spp. caught in gear other than gillnets and marketed outside the Kalakol cooperative.

Finally, a similar comparison was made between data relating to East Shore catches at the Kalokol cooperative and records from a fleet of experimental gillnets fished for two settings in Allia Bay during July 1974. Corrections were applied to the experimental catch data to allow for the different pattern of mesh size distribution found in commercial gillnets. It was assumed that this pattern was similar to that observed at Kalokol during 1973 (Table 6.29). Results from the experimental nets in Allia Bay yielded a catch per effort of 227.0 kg/F/week compared with 70.8 from the cooperative data over the same period. Allowing for subsistence, it would appear that about 68% of the commercial catch from the Eastern Shore is marketed outside the Cooperative. A similar, but less valid,comparison with the Koobi Fora experimental fishing in December 1973 produced a value of 60%. The Allia Bay observations provided an estimate for assessing the extra-cooperative trade as already shown (see page 377).

In conclusion it should be stated that comparisons of this nature depend on certain assumptions. It is assumed that F values include those fishermen engaged in extra-cooperative trade as discussed above. In regions where a significant proportion of the effort was expended in methods other than gillnetting, comparisons of total catch per effort is valid only if catch/F/week was similar for all methods. Such conditions were often fulfilled and many fishermen employed several methods simultaneously. Estimates of species composition become less reliable where catches made by alternative fishing methods differ markedly from gillnet catches. This was most noticeable in the

East Shore region where a large proportion of the catch was Sarotherodon spp., many of which were caught by gillnets used as beach seines. In this case it was better to depend on the direct estimates of the extra-cooperative trade.

COMPARISONS WITH PREVIOUS RECORDS OF CATCH PER EFFORT

Table 6.50 shows earlier records of gillnet catch per effort for Lake Turkana and provides the sources of information. Values of catch per effort from Table 6.50, together with selected observations from Table 6.38, have been plotted logarithmically in Figure 6.5b to show trends over a 12 year period. A steady fall in catches is evident in both mesh sizes. There is an indication that at Kalokol, inshore catches from 8 inch nets have decreased more rapidly than was the case in 5 inch nets. Thus catches are now smaller in the smaller mesh size than in the larger. Similar trends were noted in the Lake Chad fishery (HOPSON, 1968a). In recent years, catches from unexploited areas of the lake have been relatively high compared with commercial fishing grounds. However, catches from such virgin areas are considerably lower than those recorded at Kalokol in 1962 and 1963 when the whole lake was virtually unexploited. It would appear that some movement of fish from unexploited to exploited areas occurs, resulting in a reduction of population density in unfished areas. Such comments do not apply to newly established fisheries in which previously unexploited species have become important. Catch per effort for individual species is discussed in the next main section below.

WEEKLY COMMERCIAL CATCH PER EFFORT FOR THE MAJOR SPECIES

Numbers of fish recorded at the Cooperative Branches were summed in weekly intervals and divided by the number of commercially active fishermen, F (see page 365) for the corresponding locality and period. The resulting weekly values of catch per effort for major species, covering a period of months, are presented in Figures 6.5 c to i. The time scales on the abscissa have been adjusted to allow for an average of 5 days between capture and recording. Within each figure the same time scale is used for all histograms.

The results show marked seasonal changes in abundance. Care must be taken, however, in their interpretation. Accurate comparisons between areas and between different periods in the same area are not always possible because of changes in fishing method with locality and time. Changes in fishing grounds within a particular cooperative area also contribute to make results more difficult to interpret. These factors have been considered previously (see page 365).

The results will be discussed at length in forthcoming publications dealing with the biology of the various species concerned.

NOTES ON THE STATUS OF MAJOR COMMERCIAL SPECIES IN THE INSHORE FISHERY

INTRODUCTION

The biology of major commercial species of fish is considered in detail in Chapter 9. A brief summary of the status of each species in the inshore species follows:

Heterotis niloticus (Ehr)

This species was very localised and appeared to be restricted to shallow, well-sheltered areas bordered by beds of Typha often with Potamogeton and other submerged vegetation. Such an area between the Kerio Delta and Meriar Point yielded large catches of adult Heterotis during 1972. This fishery declined rapidly (Table 6.5). Gillnets and possibly single lines and hooks accounted for the catches. More recently catches have increased considerably in the Omo Delta. The large size of the catches (which were relatively small in number) noted by the Fish Recorder indicated that a limited number of fishermen discovered where Heterotis could be caught in quantity during 1973 and 1974. Occasional examples appear at cooperatives elsewhere but some of these occurrences may be due to fishermen transporting the fish from Todenyang and Kerio. However, there are positive records of this species for Ferguson's Gulf, Audache Lagoon (near Eliye) and Koobi Fora.

Gymnarchus niloticus Cuv. and mormyrid species

Gymnarchus and the closely related mormyrids were only recorded from the vicinity of the Omo Delta. Specimens sold at the Lowarengak Cooperative were probably transported there from the delta. The number of mormyrid species occurring in the area is uncertain due to sampling difficulties in the area of the international frontier. Reports of fishermen suggest that three distinct species are involved. Up to the present only Mormyrus kannume and Hyperopisus bebe have been positively identified. The latter was obtained in experimental gillnets and has not been observed in commercial catches.

All the species under consideration were seasonal, reaching an annual peak between July and September. This may have been due to the effect of the flooding of the River Omo on breeding cycles resulting in a concentration of fish near the river mouth. There is also evidence that Gymnarchus and the mormyrids are intolerant of the high salinities characteristic of the open lake and thus only occur in the lower delta region during the flood season when the water is greatly diluted.

Hydrocynus forskalii (Cuv.)

This predatory species occurs abundantly in the open waters of the lake both inshore and offshore. Commercial catches were high between September and November (Fig. 6.5c) in the northern part of the lake.

Gillnets account for most of the commercial catch but the mesh sizes in use have removed a negligible quantity of immature fish. Most of the catch is comprised of the larger growing females. A more substantial and regular fishery could be maintained offshore with surface set nets of 3 and 4 inch stretched mesh.

Citharinus citharus (Geoffr.)

This species formerly dominated Turkana gillnet catches but declined rapidly between 1971 and 1975. By 1974, Citharinus formed only 3% by weight of the total yield (Table 6.19.)

The largest catches are made at Todenyang and generally decrease southwards. Fish with ripe or ripening gonads were only caught at

Todenyang. Fig. 6.5d suggests a seasonal movement of the species in the lake which is consistent with a concentration of the population in the river during the flood season. Relatively little exploitation takes place in the river.

Possible reasons for the decline of Citharinus in recent years are discussed at length in Chapter 9 (see page 796).

It is possible that yields of this species may again increase during periods of heavy flooding in the future. However, under present conditions, it would be pointless to introduce regulations to conserve Citharinus if these measures were detrimental to the successful exploitation of currently important species such as Labeo horie and Lates niloticus.

Distichodus niloticus (L)

The fishery for Distichodus has in some respect had a similar history to that of Citharinus. During the early years of the Turkana gillnet fishery, Distichodus was the second most important species. Although catches have fallen since 1970, the decline has not been so rapid as in Citharinus.

Large and presumably old fish usually predominate in gillnet catches. The life cycle of Distichodus is probably similar to that of Citharinus with an annual spawning migration into the River Omo during the flood season (see Chapter 9, page 791).

The relatively large proportions of immature Distichodus caught in some areas are a consequence of the use of smaller mesh sizes. Any mesh control designed to protect this species would prejudice the exploitation of smaller, more abundant species.

Labeo horie Heckel

Few Labeo were caught prior to 1970 owing to the predominance of 7½ inch and 8 inch gillnets. The species is widespread in inshore areas of the lake at depths of less than 20 metres. Yields and catches per effort have generally increased from 1970 onwards due to the more frequent use of smaller mesh sizes and to the expansion of the fishery into new areas. Labeo horie is an anadromous species, migrating into rivers to spawn. Major pre-spawning concentrations encourage fishing activity near the mouths of rivers. This is particularly noticeable in the vicinity of the Turkwell and Kerio deltas as demonstrated by the seasonal trends in Fig. 6.5f.

Gillnet yields of Labeo have continued to rise, principally as a result of the continuing reduction of mesh sizes and the consequent capture of an increasingly large proportion of immature Labeo. Current tendencies for commercial catch per effort to rise, or in certain areas to remain steady, are thus due to the exploitation of smaller fish rather than to an increase in biomass. Labeo horie is still reasonably abundant but strict control of mesh size (see general conclusions and recommendations below) and restrictions on fishing in or near major rivers are urgently needed if a collapse of the fishery is to be avoided.

Recruitment, in the light of more recent data on young Labeo, has yet to be studied in detail but current evidence suggests that the

the numbers of juveniles may have been reduced in recent years and that the protection provided by littoral vegetation may be a limiting factor.

Barbus bynni (Forsk.)

This species increased in commercial importance between 1972 and 1974 as a result of decreasing mesh sizes combined with the increased use of bottom-set gillnets in deeper water. It appears to have a life cycle similar to Citharinus and Distichodus with a seasonal spawning migration into the River Omo during the flood period. Yields and commercial catch per effort decrease from north to south along the western shore.

Increasing proportions of immature fish have been caught and restrictions similar to those suggested for Labeo (above) are necessary to conserve this commercially important species.

Clarias lazera C & V

This anadromous silurid is confined to inshore areas, particularly to the delta regions of the Rivers Omo and Kerio. Gillnets account for most of the commercial catch but some are caught by beach seining and by longlining in shallow water. Yields in heavily exploited regions will probably not increase under present conditions (Table 6.19). Some of the 1974 catches may have originated on the eastern shore. The lakewide rise in catches of Clarias between 1972 and 1974 is attributed to an expansion of the fishery into new inshore areas, particularly the Omo delta, rather than to increased longlining. Where yields were not influenced by increasing catches from new areas, catch per effort was generally higher between August and November.

Heterobranchus sp

A clariid known as labé to Turkana fishermen has recently appeared regularly in small quantities at the Todenyang Cooperative. No complete specimen has yet been obtained for diagnosis but it seems certain from the division of the dorsal fin into rayed and adipose sections that the species concerned is Heterobranchus, probably H. longifilis C & V (see Chapter 5, page 321). It is reported that the Merille caught most of these fish with longlines in the River Omo and adjacent deltaic lagoons. The remainder were caught with large mesh gillnets. Catch per effort was seasonally high between August and November.

Bagrus bayad (Forsk.)

This species has always been caught in reasonable quantities in gillnets set inshore (page 590). Its increasing importance has been due to an expansion of longlining in deeper areas of the lake, particularly north of Central Island. Relatively rapid changes in both fishing method and locality have made it difficult to estimate catch per effort for Bagrus bayad from commercial data. However, the highest commercial values of catch per effort were generally recorded during the second half of the year, usually during September and October.

Bagrus docmac (Forsk.)

This species of minor importance was caught mostly by longlines and only occasionally by gillnets. It appears to be most plentiful in the central and southern sections of the lake as indicated by the relatively high yields and values of catch per effort in the Kerio, Eliye, Kalokol and East Shore cooperative regions. Trawl data indicate a marked preference for rocky substrata and a recent increase in commercial yield is probably due to the expansion of longlining grounds to include hard substrata near the eastern shore and in the vicinity of North and Central Islands.

Synodontis schall (Bl-Schn.)

Synodontis schall was previously utilised only for local consumption but since 1973 this ubiquitous species has been smoked for markets elsewhere in Kenya. The stimulus provided by this new outlet and the use of gillnets of smaller mesh size caused a steady increase in yield and catch per effort between 1972 and 1974. During 1974 *Synodontis schall* formed about 7% of the total yield.

Lates niloticus (L) and *Lates longispinis* (Worth.)

The two species of *Lates* are considered together because it was impracticable to distinguish between them in the processed form at the Cooperative Branches. However, it was possible to calculate the proportion of the two forms in catches from experimental gillnets and also in samples of opercular bones. During 1973 and 1974 it is estimated that *Lates longispinis* formed only between 1% and 2 % by weight of the total *Lates* catch (Table 6.19). The proportion was lower in 1972. Smaller mesh sizes, which are increasingly used in the inshore fishery, catch relatively little *Lates longispinis* although they are of a suitable size for exploitation. This is explained by the predominantly offshore distribution of the species. An increase in catches of *Lates longispinis* would be expected if gillnets were set in suitable offshore localities.

Estimated yields of *Lates* spp. increased steadily during 1972 and 1973 (Table 6.19). The rise in catches was largely due to the exploitation of new areas on the eastern shore. However, the annual catch per effort (Table 6.30) also increased at Lowerangak, Nachukui, Kataboi and Namudak. Fishermen in these cooperative regions did not often travel to the east shore and the increase in *Lates* was the result of an expansion of longlining in the open lake.

Sarotherodon niloticus (L), *Sarotherodon galilaeus* (Art.) and *Tilapia zillii* (Gerv.)

The great majority of fish listed as *Sarotherodon* in the present study are *S. niloticus*. *Sarotherodon galilaeus* has been identified in small numbers in cooperative catches and *Tilapia zillii*, which is locally common on the east shore, may also be marketed in small quantities.

The marked increase in both yield and catch per effort noted in *Sarotherodon* between 1972 and 1974 has been mostly due to the exploitation of the eastern shore with gillnets, both used in the normal way as set nets and used as beach seines. As mentioned earlier (page 362), however, a remarkably productive fishery for *S. niloticus* developed in Ferguson's Gulf during early 1975 which proved so attractive to fishermen that, for a time, fishing on the east shore stopped completely.

The inshore experimental gillnets have caught extremely few Sarotherodon in the exploited areas, even at Kerio where consistently large commercial yields have been recorded. It was found that most of the Sarotherodon on the western shore were caught by operating gillnets as beach seines, especially between the Kerio delta and Meriar Point, off Ferguson's Spit and north of Todenyang. In some areas, basket trapping played a significant but minor role. Gillnetting for Sarotherodon was evidently successful during the early days of the fishery and MANN (1964) caught large numbers by this method in the Kalokol area. It would appear that when the abundance of stocks decreases, surviving Sarotherodon remain in localised inshore areas where active fishing techniques are more successful than gillnets.

All the above cichlid species have an excellent market and smoked and fresh products command a good price in Kenya. A ready market was also found in 1975 for the whole dried but unsalted Sarotherodon produced in large quantities in the Ferguson's Gulf area as a result of the newly flourishing fishery.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

A number of conclusions have already been discussed with respect to yields, trends in catch per effort and concerning particular species of fish.

The fishery up to the end of 1974 was almost entirely restricted to inshore areas of the lake within the 15 metre contour. Open water species are being studied by other personnel of the Lake Turkana Fisheries Research Project and the present recommendations may require later modification to take into account forecasts for the offshore fishery.

The inshore fishery is unstable due to changes in gear, distribution of fishing intensity and probably also due to longer term effects of hydrological change. These factors make the overall analysis of the fishery extremely complex. Many problems could have been solved, however, if more data on catch composition, catch per effort and commercial effort had been obtained during the first 10 years of the fishery.

In spite of these limitations, a number of general conclusions are possible. Despite the overall low fishing intensity (page 352) the present study strongly suggests that current yields of several important species in the inshore fishery are not sustainable even if recruitment were stable. Citharinus and Distichodus do not now appear to warrant the drastic measure which would be required for their conservation, and there is some evidence that the reduction of the floodplain-riverine environment may have contributed to the collapse of the fishery of these species through a fall in recruitment, particularly in the case of Citharinus.

There is more hope for the future of Labeo horie and Barbus bynni although the increasing quantities of immature fish harvested, and the expansion of the Labeo fishery in the mouths of major rivers may lead to a reduction in yield. The most satisfactory measure for preventing the removal of immature Labeo and Barbus would be to allow only mesh sizes of 6" (15.2 cm) or more to be used.

Mesh size control, either voluntary or statutory, is not easy. If the decision is taken to exploit offshore resources of Alestes baremose and Hydrocynus forskalii with surface set gillnets of smaller mesh size it would be extremely difficult to prevent their use inshore.

An alternative form of control is to prohibit fishing in certain areas. This is recommended in any case for areas close to active river mouths as a means of preventing the over-exploitation of Labeo during its spawning runs. The history of Labeo victorianus in the River Nzoia (CADWALLADR, 1965) and the failure of depleted stocks to recover should be noted. Fishing has already been prohibited in the inshore areas bounding the National Park extending from the southern end of Allia Bay to just south of Ileret (Fig. 6.2b). An attempt to conserve the Turkana gillnet fishery was made in February 1975 by closing down the Todenyang Cooperative Branch. It was shown shortly afterwards that this had a negligible effect on the fishing intensity of the region, and the necessity of transporting fish to Lowarengak for sale at the cooperative has not lead to any reduction of effort at Todenyang. However, operating costs of the Cooperative will have been reduced, and a possible increase of fishing intensity may have been deterred. Actual prohibition of fishing in the Todenyang area would be difficult since a portion of the fishing grounds lies within Ethiopian territory. If it could be shown that fishing in the Omo Delta region has had a detrimental effect (which the present report does not show), a ban on the import of fish from across the frontier might be feasible. Fishing intensity could be generally reduced in the inshore areas by redeployment of effort in the expanding offshore fishery.

Catches of Lates niloticus show no signs of declining. This species is more suited to lacustrine conditions than most of the major commercial fish (HOPSON, 1969 and 1972). Much information on L. niloticus remains to be analysed but preliminary observations indicate that present catch levels are sustainable. It is recommended that more attention should be given to the potentially good market for fresh Lates in Kenya. Kalokol and Kataboi would be the most suitable locations for the development of freezing plants and for the introduction of quality control. Both are provided with good communications and reliable supplies of water.

Sarotherodon should also be marketed in fresh or smoked forms whenever possible and the economically wasteful practice of converting prime quality fish into a salted-dried form should be discouraged. The production of salted-dried fish should, however, be regarded as expedient, particularly in the case of Bagrus, Hydrocynus and other species of minor economic importance. The Cooperative can play a useful part in the diversification of the processed product by guaranteeing prices to fishermen and controlling the quality of the smoked and fresh fish.

As already indicated, the commercial fishing effort varies considerably, changing in response to a variety of factors both within and without the industry. Fishermen are highly mobile and tend to concentrate in areas where catches are currently good. The usual economic goal of a typical Lake Turkana fisherman is to provide food and basic comforts for his family and to save as much money as possible for investment in livestock. The traditional nomadic way of life is regarded so highly that skilled and successful fishermen who have built up sufficient capital in livestock frequently give up fishing and revert to pastoralism. Proposals for increasing the efficiency of the gear should take into account the labour-intensive nature of the existing fishery. In the interests of the overall prosperity of the region, changes involving a reduction of manpower would be undesirable. The loan of money for motorised craft should be approved only after careful consideration. The resources of the fishery as a whole are probably much less than was originally estimated and a situation where overfishing is encouraged to enable loans to be repayed should be avoided. A well documented example of 'economic overfishing' in Lake Chad (HOPSON, 1968b) is relevant in many respects.

Under correct management the fishery will yield from 3000 to 5000 tonnes of fresh fish per year in areas of the lake at present exploited, providing no significant hydrological changes occur.

The data on which this appraisal is based were collected over a relatively short period compared with the total period of exploitation. In view of the present instability of the fishery, it is imperative that the collection of statistics continues. This can be done with relatively minor expense and the benefits gained from correct management are considerable.

Routine data should be collected as follows:

(a) Fish Recorders should continue to monitor the numbers of each species of fish entering the cooperatives and to measure monthly samples of the more important forms. Estimates of commercial effort should be continued using the methods outlined on pages 371 to 379 . Fish Recorders should also be employed to carry out similar work on smoked fish traded outside the Cooperative. In order to ensure that the standard of work of the recorders is maintained, a supervisor should visit them at least monthly to check records and collect results. Ideally this inspection should be carried out by the officer responsible for the analysis of the results.

(b) Gillnetting with graded fleets of 50 yd (45.7 m) nets with mesh sizes ranging from 2 inches to 8 inches in 1 inch intervals should be carried out at inshore and offshore stations in exploited and unexploited areas. As a general guide, an absolute minimum of 52 sets per annum at each station in exploited areas, and about half that number in unexploited areas should be made.

(c) Sampling for post-larval and young fish in suitable areas should continue, so as to provide some guide to future recruitment of commercially important fish. The monthly samples with the fine shore seine and coarse Plymouth tow net should be continued at Todenyang, Ferguson's Gulf and Kerio.

REFERENCES

CADWALLADR, D A (1965). The decline in the *Labeo victorianus* Blgr (Pisces, Cyprinidae) fishery of Lake Victoria and an associated deterioration in some indigenous fishing methods in the Nzoia River, Kenya. *E. Afr. agric. For. J.* *30*: 249-256.

DAGET, J (1962). Le genre *Citharinus* (Poissons, Characiformes). *Rev. Zool. Bot. afr.* *66*: 81-106

GULLAND, J A (1964). Mannual of methods of fish population analysis. *FAO Fish. Tech. Pap.* *(40)* : 1-61

HOHNEL, L von (1894). *Discovery of Lakes Rudolf and Stefanie.* Longmans, London.

HOLT, S J (1963). A method for determining gear selectivity and its application. *Spec. Publs. int. Commn. NW Atlant. Fish,* *(5)* : 106-115.

HOPSON, A J (1968a). The gillnet fisheries of Lake Chad. *Fed. Fish Nigerial Occas.* *Pap.* *(11)* : 1-64.

HOPSON, A J (1968b). Report on research projects, Malamfatori, Lake Chad: economic factors and the regulation of the gillnet fisheries of Lake Chad. *Rep.* *Fed. Fish Service Nigeria.* 1968 : 58-65

HOPSON, A J (1969). A description of the pelagic embryos and larval stages of *Lates niloticus* (L) (Pisces, Centropomidae) from Lake Chad with a review of early development in lower percoid fishes. *Zool. J. Linn. Soc.* *48* : 117-134

HOPSON, A J (1972). A study of the nile perch (*Lates niloticus* (L), Pisces, Centropomidae) in Lake Chad. *Overseas Res. Publ.* *(19)* : 1-93 Foreign and Commonwealth Office, London.

HULOT, A (1951). Observations sur la biologie de *Citharinus congicus* et de *C. gibbosus* dans la region forestière congolaise aux environs de Yangambi. *Congr. int. limnol.* *11* : 201-209.

LELEK, A (1973). Sequence of changes in fish populations of the new tropical man-made lake, Kainji, Nigeria, West Africa. *Arch. Hydrobiol.* *71* : 381-420

MANN, M J (1964). Report on a fisheries survey of Lake Rudolf, Kenya. *Rep. E. Afr. Freshwat. Fish. Org.* 1962/63: 42-52

WORTHINGTON, E B (1929). *A report on the fishery survey of Lakes Albert and Kioga March-July 1928.* Crown Agents, London.

WORTHINGTON, E B and RICARDO, C K (1936). Scientific results of the Cambridge Expedition to the East African lakes, 1930-31. The fish of Lake Rudolf and Lake Baringo. *Zool. J. Linn. Soc.* *39* : 353-389

TABLE 6.1

Estimates of lake area lying within various depth contours. The areas are expressed as percentages of the total lake area (7560 km^2) in the final column.

Depth less than (metres)	Area (km^2)	% total area
10	1584	21
15	2170	29
20	2681	35

TABLE 6.2

Estimates of the areas fished in the various cooperative regions during 1974. The areas are expressed as percentages of the total area of fishing grounds in the final column.

Name of Area	Buying Point	Area fished (km^2)	% of total
Todenyang/Omo Delta	Todenyang	183	17
Lowarengak	Lowarengak	109	10
Nachukui/N. Island	Nachukui	118	11
Kataboi	Kataboi	116	11
Namudak	Namudak & Kalokol	44	4
Kalokol/F. Gulf	Kalokol	78	7
E. Shore between Moite & Allia Bay/Central Is.	Kalokol	12	1
East Shore (Allia Bay)	Kalokol	90*	8
Eliye	Eliye	61	6
Moite Bay to Otus Island	Eliye	43	4
Kerio Bay	Kerio	179	16
Otus Island to Sandy Bay	Kerio	58*	5
	Total, maximum area:	1091 km^2	

*Lightly or temporarily exploited areas = 148 km^2

Total area regularly fished = 943 km^2

TABLE 6.3

Conversion factors for the calculation of fresh weight from processed weight in four important commercial species. The values were obtained by estimating the fresh weights of dried fish from opercular measurements using the regressions shown in Appendices 6.II.2 and 6.II.9.

Species	Sample size	TL range	Mean conversion factor ± S.D.	95% confidence limits for mean prediction
Citharinus	28	43-61	2.71 ± 0.51	± 0.20
Distichodus	26	53-83	2.91 ± 0.41	± 0.17
Labeo	31	55-75	3.10 ± 0.56	± 0.21
Lates niloticus	10	52-82	2.62 ± 0.73	± 0.55

TABLE 6.4

Means of conversion factors calculated each month at various cooperatives to represent the weight loss during the production of salted-dried fish from fresh fish. The values were obtained by comparing fresh weights estimated from the Fish Recorder's data with dried weights recorded by the Cooperative at the time of purchase.

Cooperative branch	Mean conversion rate ± s.dev.
Todenyang	2.60 ± 0.26
Lowarengak	2.63 ± 0.27
Nachukui	2.80 ± 0.26
Kataboi	2.55 ± 0.29
Kerio	2.94 ± 0.37

TABLE 6.5

Monthly total numbers of each species of fish purchased by the Kerio cooperative branch during the period July 1972 to December 1974.

	Heterotis	Mormyridae spp.	Gymnarchus	Alestes spp.	Hydrocynus	Citharinus	Distichodus	Labeo	Barbus bynni	Clarias	Heterobranchus	Bagrus bayad	Bagrus docmac	Lates spp.	Sarotherodon spp.
1972															
Jul	500	-	-	-	10	950	570	15340	26	340	-	23	8	1260	5240
Aug	240	-	-	-	30	2250	440	13880	72	200	-	80	14	1290	4650
Sep	150	-	-	1	57	2560	570	13150	48	220	-	120	17	1300	4050
Oct	49	-	-	5	45	1200	2790	20610	53	190	-	72	33	1590	3750
Nov	41	-	-	-	54	530	2770	10330	270	150	-	140	33	1680	1230
Dec	13	-	-	2	67	490	2040	3890	59	82	-	180	17	1990	1130
1973															
Jan	56	-	-	-	71	550	520	2210	32	140	-	160	9	1670	1260
Feb	130	-	-	-	39	510	940	1620	14	310	-	160	9	1730	1130
Mar	300	-	-	-	41	850	560	1540	11	550	-	180	17	2040	3380
Apr	290	-	-	-	26	290	100	3950	6	500	-	190	11	1730	1070
May	110	-	-	1	24	430	65	8450	21	390	-	290	10	2200	2450
Jun	72	-	-	-	7	67	30	11674	150	730	-	260	15	1480	3330
Jul	36	-	-	1	15	54	43	15440	270	160	-	120	20	1690	4710
Aug	39	-	-	-	21	160	73	18940	650	1160	-	230	32	970	1850
Sep	63	-	-	-	38	59	910	5190	190	600	-	290	33	1280	4090
Oct	21	-	-	-	31	420	850	10290	450	700	-	370	35	1000	6350
Nov	2	-	-	2	91	740	260	5720	55	140	-	360	20	1140	6070
Dec	1	-	-	-	30	550	200	2090	82	170	-	270	20	1210	3980
1974															
Jan	5	-	-	-	110	840	110	2080	150	480	-	430	43	2760	5610
Feb	14	-	-	-	36	560	280	1280	100	200	-	270	34	3290	2030
Mar	5	-	-	-	36	1310	120	1420	98	47	-	96	76	1850	1380
Apr	9	-	-	-	18	400	140	11600	220	280	-	220	150	2260	2510
May	5	-	-	-	13	130	130	13450	120	270	-	160	26	1540	2970
Jun	5	-	-	-	220	670	43	8940	37	210	-	160	34	1510	3290
Jul	15	-	-	-	210	390	100	10720	120	450	-	400	58	1630	9004
Aug	10	-	-	-	11	550	86	4310	140	310	-	170	41	1020	5890
Sep	2	-	-	-	130	560	140	4390	170	260	-	290	55	1300	6920
Oct	2	-	-	-	77	210	230	1920	31	70	-	410	35	1410	7540
Nov	2	-	-	-	4	280	78	680	18	30	-	150	23	720	2150
Dec	2	-	-	-	71	190	17	1350	41	130	-	220	24	1560	2690

TABLE 6.6

Monthly total numbers of each species of fish purchased by the Eliye cooperative branch during the period July 1972 to January 1974.

	Heterotis	Mormyridae spp.	Gymnarchus	Alestes spp.	Hydrocynus	Citharinus	Distichodus	Labeo	Barbus bynni	Clarias	Heterobranchus	Bagrus bayad	Bagrus docmac	Lates spp.	Sarotherodon spp.
1972															
Jul	3	-	-	-	1	780	47	140	5	-	-	3	16	220	520
Aug*	-	-	-	-	-	14	3	8	-	-	-	-	-	1	-
Sep	-	-	-	-	7	1340	61	460	9	7	-	26	5	61	490
Oct							NO DATA								
Nov							NO DATA								
Dec	-	-	-	-	42	350	59	150	3	-	-	3	-	200	62
1972															
Jan	-	-	-	-	18	140	83	260	6	-	-	31	-	400	810
Feb	-	-	-	-	12	370	91	160	5	8	-	37	1	850	3710
Mar	-	-	-	-	6	950	250	140	-	18	-	31	3	710	2270
Apr	6	-	-	-	45	430	220	680	22	120	-	130	38	1250	2780
May	5	-	-	-	4	92	250	500	6	7	-	12	31	870	2290
Jun	7	-	-	-	8	91	59	210	1	7	-	8	35	440	3010
Jul	7	-	-	-	5	53	44	650	-	6	-	6	5	440	1290
Aug	2	-	-	-	13	510	280	1100	190	68	-	60	89	580	2230
Sep	-	-	-	-	3	1150	250	920	-	18	-	59	18	390	290
Oct	1	-	-	-	12	810	260	1030	38	23	-	86	190	940	380
Nov	-	-	-	-	49	320	120	470	-	34	-	50	68	810	240
Dec	-	-	-	-	13	180	9	320	-	23	-	93	16	310	67
1974															
Jan	-	-	-	-	34	150	150	730	14	34	-	100	38	460	370

*incomplete data

TABLE 6.7

Monthly total numbers of each species of fish originating from the Kalokol area, purchased by the Kalokol cooperative branch during the period August 1972 to December 1974.

	Heterotis	Mormyridae spp.	Gymnarchus	Alestes spp.	Hydrocynus	Citharinus	Distichodus	Labeo	Barbus bynni	Clarias	Heterobranchus	Bagrus bayad	Bagrus docmac	Lates spp.	Sarotherodon spp.
1972															
Aug	-	-	-	-	9	1250	780	1090	18	2	-	10	16	280	110
Sep	-	-	-	-	13	450	470	780	17	3	-	19	-	160	80
Oct	-	-	-	-	62	1200	1310	1810	38	6	-	490	4	440	12
Nov	1	-	-	-	44	5820	1690	2310	91	1	-	160	6	380	13
Dec	-	-	-	-	23	1580	610	1110	170	-	-	190	8	280	-
1973															
Jan	-	-	-	-	27	1740	410	410	39	2	-	150	2	240	3
Feb	-	-	-	-	12	4650	520	680	15	-	-	120	2	230	1
Mar	-	-	-	2	11	1650	350	370	4	-	-	170	13	300	-
Apr	1	-	-	-	2	130	180	270	5	4	-	110	5	160	43
May	1	-	-	5	14	27	210	460	2	2	-	270	8	120	43
Jun	-	-	-	24	28	75	150	1000	12	2	-	240	12	150	170
Jul*	-	-	-	-	6	620	85	810	73	3	-	210	20	160	1550
Aug*	-	-	-	5	15	1300	110	780	66	6	-	730	67	510	1310
Sep*	-	-	-	-	16	1640	380	920	83	61	-	1700	69	490	1060
Oct*	-	-	-	-	91	3810	720	2470	180	80	-	1980	63	1260	1900
Nov	-	-	-	-	52	1320	360	1300	110	86	-	690	30	680	560
Dec	-	-	-	-	69	600	180	660	44	130	-	920	21	640	110
1974															
Jan	-	-	-	-	29	950	74	660	50	310	-	1200	35	880	340
Feb	-	-	-	-	5	170	17	120	38	76	-	530	29	320	66
Mar	-	-	-	-	7	240	34	230	7	22	-	490	11	320	110
Apr	-	-	-	-	4	290	13	350	22	9	-	890	12	350	110
May	-	-	-	-	3	220	27	370	31	2	-	1000	24	300	42
Jun	-	-	-	-	2	64	12	320	19	2	-	1140	16	230	3
Jul	-	-	-	-	5	160	15	670	19	11	-	870	25	290	12
Aug	-	-	-	-	1	360	16	570	9	27	-	980	17	170	8
Sep	-	-	-	-	11	49	35	520	12	22	-	1830	28	380	9
Oct	-	-	-	-	9	32	14	250	15	32	-	770	15	260	1
Nov	-	-	-	-	61	58	18	390	41	360	-	1340	32	440	3
Dec	-	-	-	-	27	48	48	160	13	72	-	1520	14	390	340

*Includes considerable number from Eastern shore.

TABLE 6.8

Monthly total numbers of each species of fish originating from the East Shore and Central Island areas, purchased by the Kalokol cooperative branch during the period November 1973 to December 1974.

	Heterotis	Mormyridae spp.	Gymnarchus	Alestes spp.	Hydrocynus	Citharinus	Distichodus	Labeo	Barbus bynni	Clarias	Heterobranchus	Bagrus bayad	Bagrus docmac	Lates spp.	Sarotherodon spp.
1973															
Nov	-	-	-	-	60	2320	440	1530	100	270	-	960	29	1520	820
Dec	-	-	-	-	22	1050	160	810	32	1140	-	1360	44	1500	410
1974															
Jan	-	-	-	-	2	1020	47	540	4	2000	-	1570	49	2870	560
Feb	-	-	-	-	11	430	12	360	52	22	-	1590	14	1010	240
Mar	-	-	-	-	17	800	39	290	23	58	-	1850	43	1130	140
Apr	-	-	-	-	8	780	87	950	31	20	-	2000	42	770	130
May	-	-	-	-	13	690	74	620	33	15	-	3420	29	610	16
Jun	-	-	-	-	-	270	3	260	11	9	-	3980	21	610	47
Jul	-	-	-	-	-	170	5	150	10	11	-	2960	53	570	79
Aug	-	-	-	-	5	820	8	490	20	31	-	3600	39	650	41
Sep	-	-	-	-	13	240	28	420	14	42	-	4930	39	1170	8
Oct	-	-	-	-	17	170	28	680	19	180	-	4430	21	1570	8
Nov	-	-	-	-	73	97	27	500	18	290	-	2260	38	600	6
Dec	-	-	-	-	2	85	110	280	16	210	-	4220	20	790	3

TABLE 6.9

Monthly total numbers of each species of fish originating from the Namudak area, purchased by the Kalokol cooperative branch during the period August 1972 to December 1974.

	Heterotis	Mormyridae spp.	Gymnarchus	Alestes spp.	Hydrocynus	Citharinus	Distichodus	Labeo	Barbus bynni	Clarias	Heterobranchus	Bagrus bayad	Bagrus docmac	Lates spp.	Sarotherodon spp.
1972															
Aug	-	-	-	-	9	240	380	720	16	-	-	1	-	65	1
Sep	1	-	-	-	9	180	510	690	28	-	-	500	-	71	2
Oct	-	-	-	-	14	230	1920	1860	20	-	-	1660	2	330	1
Nov	-	-	-	-	16	1250	920	1500	61	-	-	390	2	200	2
Dec	-	-	-	-	9	410	380	770	180	-	-	500	1	140	1
1973															
Jan	-	-	-	-	7	510	470	510	23	-	-	470	2	98	2
Feb	-	-	-	-	1	1060	870	1170	7	-	-	320	1	130	2
Mar	-	-	-	-	6	300	570	390	7	-	-	370	6	96	-
Apr	-	-	-	-	4	19	220	200	2	-	-	210	3	30	-
May	-	-	-	225	15	2	240	330	9	-	-	350	7	38	-
Jun	-	-	-	10	11	9	130	710	4	-	-	270	9	45	3
Jul	-	-	-	-	1	57	110	740	35	-	-	280	5	39	5
Aug	-	-	-	-	1	100	100	410	17	1	-	390	16	62	180
Sep	-	-	-	-	5	100	380	510	25	9	-	364	10	120	240
Oct	-	-	-	-	20	670	1030	2130	58	10	-	840	21	360	530
Nov	-	-	-	-	54	570	1000	1840	83	20	-	600	27	560	190
Dec	-	-	-	-	14	320	270	940	100	50	-	960	13	350	43
1974															
Jan	-	-	-	-	43	160	260	1000	25	53	-	740	5	400	100
Feb	-	-	-	-	10	110	150	1110	25	14	-	1400	10	360	79
Mar	-	-	-	-	7	21	59	520	4	5	-	660	3	84	1
Apr	-	-	-	-	15	180	73	590	68	29	-	450	15	170	8
May	-	-	-	-	2	20	84	470	33	2	-	330	9	98	6
Jun	-	-	-	-	4	4	41	710	5	-	-	980	1	110	5
Jul	-	-	-	-	8	66	130	1930	51	-	-	700	7	220	13
Aug	-	-	-	-	11	5	50	570	16	2	-	280	2	70	6
Sep	1	-	-	-	13	30	71	620	13	2	-	900	4	300	3
Oct	-	-	-	-	4	23	95	440	8	34	-	620	2	230	-
Nov	-	-	-	-	98	98	35	440	32	83	-	990	15	400	8
Dec	-	-	-	-	15	53	69	260	5	69	-	1240	21	430	-

TABLE 6.10

Monthly total numbers of each species of fish purchased by the Kataboi cooperative branch during the period July 1972 to December 1974.

	Heterotis	Mormyridae spp.	Gymnarchus	Alestes spp.	Hydrocynus	Citharinus	Distichodus	Labeo	Barbus bynni	Clarias	Heterobranchus	Bagrus bayad	Bagrus docmac	Lates spp.	Sarotherodon spp.
1972															
Jul	-	-	-	-	2	2150	1650	780	6	-	-	-	-	190	2
Aug	-	-	-	-	1	650	1450	620	42	-	-	-	-	180	-
Sep	-	-	-	-	4	210	2380	1130	53	-	-	-	-	350	2
Oct	-	-	-	-	7	110	1320	1240	76	2	-	29	-	270	4
Nov	-	-	-	-	17	900	1480	2110	180	-	-	100	2	210	3
Dec	-	-	-	-	4	800	2540	2830	290	-	-	65	-	260	1
1973															
Jan	-	-	-	-	14	1010	3220	4110	460	-	-	77	4	210	8
Feb	-	-	-	-	3	1430	1840	2480	310	-	-	38	6	150	32
Mar	-	-	-	-	3	240	810	1190	75	-	-	66	3	94	11
Apr	-	-	-	-	6	46	430	1140	43	-	-	67	5	77	2
May	-	-	-	-	12	9	380	830	72	-	-	160	6	100	-
Jun	-	-	-	-	7	12	360	920	130	-	-	420	13	140	4
Jul	-	-	-	-	15	12	990	2210	290	1	-	210	7	180	5
Aug	-	-	-	-	9	35	1110	2520	410	-	-	330	16	230	2
Sep	-	-	-	-	14	24	2190	4720	390	-	-	1020	8	440	6
Oct	-	-	-	-	7	10	790	6920	950	2	-	780	6	280	8
Nov	-	-	-	-	18	31	340	4160	3000	5	-	610	12	480	32
Dec	-	-	-	-	8	41	330	4210	1540	-	-	180	9	380	72
1974															
Jan	-	-	-	-	5	68	200	3330	410	-	-	300	29	380	38
Feb	-	-	-	-	2	34	140	2290	350	-	-	90	8	170	83
Mar	-	-	-	-	27	32	170	2850	130	-	-	70	11	140	100
Apr	-	-	-	-	12	43	170	4760	390	1	-	210	29	170	12
May	-	-	-	-	19	25	230	5360	320	-	-	230	20	210	12
Jun	-	-	-	-	7	25	220	1960	420	-	-	320	12	360	-
Jul	-	-	-	-	20	21	510	4520	490	1	-	490	19	450	-
Aug	-	-	-	-	26	31	510	3590	360	-	-	520	25	520	1
Sep	-	-	-	-	11	10	170	2950	220	3	-	1190	16	780	1
Oct	-	-	-	-	29	10	150	2880	210	8	-	1110	17	880	-
Nov	-	-	-	-	54	15	370	3290	1440	-	-	1640	10	840	1
Dec	-	-	-	-	73	6	810	3320	690	-	-	1810	68	830	2

TABLE 6.11

Monthly total numbers of each species of fish purchased by the Nachukui cooperative branch during the period May 1972 to December 1974.

	Heterotis	Mormyridae spp.	Gymnarchus	Alestes spp.	Hydrocynus	Citharinus	Distichodus	Labeo	Barbus bynni	Clarias	Heterobranchus	Bagrus bayad	Bagrus docmac	Lates spp.	Sarotherodon spp.
1972															
May*	-	-	-	-	-	1020	740	750	41	-	-	-	-	170	-
Jun	-	-	-	-	-	270	830	820	13	-	-	-	-	450	2
Jul	-	-	-	-	-	190	1010	850	140	-	-	-	-	690	1
Aug	-	-	-	-	-	210	1120	870	170	-	-	-	-	740	-
Sep	-	-	-	-	6	190	900	1010	74	-	-	-	-	370	-
Oct	-	-	-	-	61	210	630	1300	93	1	-	1	-	270	1
Nov	-	-	-	-	-	420	820	1180	1030	-	-	37	-	480	-
Dec	-	-	-	-	-	99	3910	2950	860	-	-	-	-	320	-
1973															
Jan	-	-	-	-	1	190	3180	3470	1680	-	-	-	-	300	-
Feb	-	-	-	-	-	420	420	1350	1700	-	-	1	-	220	-
Mar	-	-	-	-	-	83	110	810	1200	-	-	-	-	220	-
Apr	-	-	-	-	1	8	160	880	470	-	-	-	-	160	1
May	-	-	-	-	5	2	180	610	170	-	-	390	3	380	-
Jun	-	-	-	-	18	2	370	1050	1610	-	-	350	-	810	1
Jul	-	-	-	-	1	1	1300	2140	1180	-	-	150	-	460	-
Aug	-	-	-	-	37	68	470	1610	1510	-	-	190	-	950	-
Sep	1	-	-	-	12	120	1980	3450	2550	-	-	86	-	1120	2
Oct	-	-	-	-	92	53	730	4320	1490	1	-	190	-	210	-
Nov	-	-	-	-	29	12	350	2590	11490	3	-	180	-	240	9
Dec	-	-	-	-	11	8	1170	5870	8150	-	-	55	-	250	12
1974															
Jan	-	-	-	-	17	9	230	2220	2860	1	-	30	-	200	3
Feb	-	-	-	-	4	6	250	1330	530	-	-	300	-	120	35
Mar	-	-	-	-	12	11	210	1300	190	-	-	600	-	170	-
Apr	-	-	-	-	23	72	300	5190	700	-	-	500	-	410	4
May	-	-	-	-	17	7	120	3630	760	-	-	1060	-	740	-
Jun	-	-	-	-	12	2	170	1550	760	-	-	930	-	830	-
Jul	-	-	-	-	11	6	62	840	1120	-	-	380	-	680	-
Aug	-	-	-	-	12	14	340	1760	1090	-	-	300	-	980	-
Sep	-	-	-	-	56	10	200	2470	1310	1	-	330	-	600	1
Oct	-	-	-	-	190	3	220	2350	440	-	-	140	-	320	-
Nov	-	-	-	-	20	-	1130	5240	2990	-	-	400	-	800	-
Dec	-	-	-	-	21	-	780	4010	1640	-	-	390	-	670	-

* From 5 May.

TABLE 6.12

Monthly total numbers of each species of fish purchased by the Lowarengak cooperative branch during the period May 1972 to December 1974.

	Heterotis	Mormyridae spp.	Gymnarchus	Alestes spp.	Hydrocynus	Citharinus	Distichodus	Labeo	Barbus bynni	Clarias	Heterobranchus	Bagrus bayad	Bagrus docmac	Lates spp.	Sarotherodon spp.
1972															
May*	-	-	-	-	-	9040	2680	300	170	-	-	-	1	280	-
Jun	-	-	-	-	-	650	330	210	120	-	-	-	-	600	-
Jul	-	-	-	-	-	700	510	410	1180	-	-	-	-	950	-
Aug	-	-	-	-	1	590	640	290	1840	-	-	-	-	480	-
Sep	-	-	-	-	1	880	300	520	800	-	-	-	-	210	-
Oct	1	-	-	-	34	1320	340	830	450	2	-	2	-	370	2
Nov	-	-	-	-	48	4020	650	970	920	1	-	2	-	280	1
Dec	-	-	-	-	14	1460	710	290	5220	-	-	1	-	280	1
1973															
Jan	-	-	-	-	7	3150	920	750	4470	-	-	21	-	750	3
Feb	1	-	-	-	4	6450	950	1260	2390	-	-	19	-	340	2
Mar	-	-	-	-	1	2010	540	880	370	-	-	-	-	77	-
Apr	-	-	-	-	2	260	310	1170	430	-	-	15	-	99	-
May	-	-	-	-	6	250	700	1230	2030	-	-	170	-	1000	-
Jun	-	-	-	-	4	130	1860	3920	2250	9	-	150	3	1310	1
Jul	-	-	-	-	11	180	1060	4780	3400	2	-	390	-	1240	11
Aug	-	-	-	-	52	360	210	2110	2560	1	1	390	4	760	4
Sep	1	2	7	1	390	1350	360	4070	2340	12	-	330	3	670	6
Oct	2	1	-	-	520	1450	460	3790	3017	10	-	170	2	570	19
Nov	2	1	-	-	220	170	420	6420	16260	8	-	56	-	200	7
Dec	-	-	-	-	14	54	99	240	28750	-	-	38	-	100	18
1974															
Jan	-	-	-	-	26	110	24	900	11250	1	-	55	-	140	23
Feb	-	-	-	-	31	170	14	4520	1270	-	-	260	-	180	60
Mar	79	-	-	-	8	290	260	2610	1530	34	-	530	-	740	41
Apr	79	1	3	-	3	260	550	7070	2640	8	-	310	-	630	-
May	47	2	1	-	9	72	150	2580	3010	2	-	370	2	1110	3
Jun	79	-	4	-	12	88	140	2170	3470	27	-	270	-	1090	2
Jul	3	3	2	-	10	61	83	1800	4560	16	-	550	4	1330	-
Aug	17	8	9	-	19	130	82	2130	5870	7	-	700	9	830	11
Sep	1	-	-	-	240	100	120	2620	8360	29	-	440	12	780	11
Oct	2	-	-	-	460	52	77	1810	4490	11	-	250	7	590	4
Nov	-	-	-	-	120	26	130	1200	17240	5	-	390	18	620	8
Dec	-	-	-	-	16	26	130	490	15190	1	-	330	13	540	-

* From 5 May.

TABLE 6.13

Monthly total numbers of each species of fish purchased by the Todenyang cooperative branch during the period May 1972 to December 1974.

	Heterotis	Mormyridae spp.	Gymnarchus	Alestes spp.	Hydrocynus	Citharinus	Distichodus	Labeo	Barbus bynni	Clarias	Heterobranchus	Bagrus bayad	Bagrus docmac	Lates spp.	Sarotherodon spp.
1972															
May*	-	-	-	-	-	8660	4530	150	120	-	-	-	2	260	-
Jun	-	-	-	-	-	450	2920	160	430	-	-	-	-	1110	-
Jul	-	-	-	-	-	2980	1650	330	3220	-	-	-	-	2410	-
Aug	-	-	-	-	1	8950	1070	460	2780	-	-	-	-	1610	-
Sep	3	-	-	-	24	10420	1470	700	1270	-	-	-	-	2140	-
Oct	1	-	3	-	250	12480	1540	1860	1190	19	-	6	2	2510	1
Nov	1	-	7	-	58	14890	1640	1210	1070	8	-	-	3	1330	-
Dec	-	-	-	-	1	5770	490	360	2010	-	-	-	1	860	-
1973															
Jan	3	-	-	-	7	20660	1460	580	5400	28	1	15	2	1060	2
Feb	-	-	2	-	-	7280	1790	480	1210	-	-	5	-	200	-
Mar	-	-	-	-	-	10640	3000	1710	650	-	-	1	1	350	1
Apr	11	5	1	-	-	2190	2060	4490	1310	4	-	1	-	1290	1
May	31	2	1	68	28	3190	4840	4690	2850	13	8	80	21	3570	-
Jun	11	-	4	9	22	1140	1650	4780	3900	31	5	160	2	2930	-
Jul	24	-	77	-	31	3050	840	4300	4390	32	6	170	-	2940	-
Aug	58	7	590	2	220	6940	2450	2900	3840	38	60	250	8	1060	3
Sep	33	44	480	1	1490	16470	1770	2940	2290	65	50	290	4	1320	17
Oct	50	29	190	-	2500	23250	1710	3850	2120	93	35	290	7	1760	25
Nov	21	29	150	-	1610	6110	1640	4120	8320	100	17	320	6	2610	28
Dec	40	5	71	-	340	6900	1210	5990	23140	94	26	250	8	2970	250
1974															
Jan	42	29	73	-	72	8090	1180	7610	15300	110	1	200	6	1940	390
Feb	190	3	83	-	46	3370	910	6590	6110	240	2	130	3	1590	230
Mar	1990	3	8	-	82	1760	3250	10680	8820	630	1	310	4	2330	160
Apr	550	16	48	-	35	1200	1700	11280	7470	300	-	460	1	1780	89
May	400	22	42	-	95	720	620	6390	6320	200	-	290	5	1650	18
Jun	1300	49	180	-	52	390	420	5610	4370	230	-	280	4	1880	110
Jul	470	380	590	-	67	1770	540	7650	9310	240	-	1150	24	1640	270
Aug	110	130	400	-	310	1810	660	3720	4750	250	-	670	5	830	180
Sep	76	29	220	-	2950	2260	720	4040	7660	160	31	610	6	1070	490
Oct	91	77	180	-	5000	1670	660	2990	8280	520	12	1000	7	2010	200
Nov	46	29	180	-	1810	850	890	3500	12600	380	4	780	1	2590	180
Dec	48	2	29	-	120	1010	1090	4430	14990	250	-	280	1	1440	9

* From 4 May.

TABLE 6.14

Equivalent fresh weight of each species of fish in tonnes per annum received by cooperative branches during 1972, 1973 and 1974.

Species	Yr	Kerio	Eliye	East Shore	Kalokol	Namudak	Kataboi	Nachukui	Lowarengak	Todenyang	Total all regions
Heterotis niloticus	72	5	+	NF	+	+	-	+	+	+	5
	73	1	+	*	+*	-	-	-	+	1	2
	74	+	-	-	-	+	-	-	1	16	17
Mormyridae	72	-	-	NF	-	-	-	-	-	-	-
	73	-	-	-	-	-	-	-	+	+	+
	74	-	-	-	-	-	-	-	-	1	1
Gymnarchus niloticus	72	-	-	NF	-	-	-	-	-	+	+
	73	-	-	-	-	-	-	-	+	5	5
	74	-	-	-	-	-	-	-	+	6	6
Hydrocynus forskalii	72	1	+	NF	+	+	+	+	+	1	3
	73	1	+	*	1*	+	+	+	3	16	22
	74	2	+	+	+	+	+	1	2	28	35
Citharinus citharus	72	34	19	NF	51	13	21	23	144	281	586
	73	28	11	*	52*	9	7	2	33	280	410
	74	14	7	13	6	2	1	+	3	63	108
Distichodus niloticus	72	83	20	NF	44	32	54	65	48	134	480
	73	20	7	*	15*	18	31	38	35	123	287
	74	6	2	2	1	4	9	14	7	63	107
Labeo horie	72	276	13	NF	52	37	43	42	16	26	505
	73	188	19	*	37*	29	102	87	101	124	688
	74	143	16	16	13	25	114	95	86	228	738
Barbus bynni	72	1	+	NF	3	2	2	6	29	43	87
	73	4	+	*	2*	1	13	56	99	134	311
	74	2	+	1	1	1	10	27	145	254	441
Clarias lazera	72	7	+	NF	+	-	+	+	+	+	8
	73	20	1	*	5*	+	+	+	+	3	30
	74	10	1	9	2	1	+	+	1	18	41
Heterobranchus	72	-	-	NF	-	-	-	-	-	-	-
	73	-	-	-	-	-	-	-	+	1	1
	74	-	-	-	-	-	-	-	-	+	+
Bagrus bayad	72	1	+	NF	2	5	+	+	+	+	10
	73	4	1	*	16*	10	6	4	3	3	46
	74	4	2	74	19	23	17	13	11	12	174
Bagrus docmac	72	1	1	NF	+	+	+	-	+	+	2
	73	1	1	*	1*	+	+	+	+	+	3
	74	1	1	1	1	+	1	-	+	+	6
Lates spp.	72	139	37	NF	22	5	7	18	19	89	337
	73	106	40	*	43*	8	10	23	32	121	383
	74	111	44	74	21	11	19	26	38	112	457
Sarotherodon spp.	72	53	25	NF	1	+	+	+	+	+	78
	73	44	29	*	12*	2	+	+	+	+	87
	74	78	30	2	2	+	+	+	+	3	116
All species	72	601	117	NF	176	94	127	155	257	575	2101
	73	407	110	*	184	78	170	210	306	812	2276
	74	372	104	191	66	69	171	177	295	805	2250

NF = no fishing in East Shore (via Kalokol) region prior to 1973.

* during 1973 Kalokol figures include fish originating from East Shore but not recorded separately.

TABLE 6.15

Showing the species composition of fish consumed locally for subsistence in each of three cooperative regions. Estimated weights of each species are expressed as a percentage of the total weight utilised for subsistance.

Region	Months in 1973	Hydrocynus	Synodontis schall	Bagrus bayad	Labeo	Clarias
Todenyang	July to Nov	61	15	23	-	-
Kalokol	Jan, Feb, May	62	25	13	-	-
Kerio	Mar to Nov	-	16	32	52	-

TABLE 6.16

Showing the monthly quantity of smoked fish (fresh weight equivalent in tonnes) exported from Kalokol, based on tax records.

Month	1973	1974	1975
January	13.3	4.6	169.0
February	22.1	15.7	279.0
March	21.7	10.9	
April	17.3	15.7	
May	23.3	14.5	
June	16.1	30.8	
July	15.0	44.8	
August	10.3	48.9	
September	4.9	59.0	
October	9.1	92.9	
November	8.8	122.3	
December	8.3	149.3	
Totals	170	609	

TABLE 6.17

Species composition (percentage weight) of fish involved in smoked fish trade.

Year	*Sarotherodon* spp.	*Labeo horie*	*Synodontis schall*	*Barbus bynni*
1973	60	30	8	2
1974	45	35	20	-

TABLE 6.18

Estimates of subsistence and extra-cooperative trade (in fresh tonnes per annum) for each cooperative region during the period 1972 to 1974. Subsistence values are shown in normal type face and figures for extra-cooperative trade in italics.

Species	Year	Kerio		Eliye		E. Shore		Kalokol		Namudak		Kataboi		Nachakui		Lowarengak		Todenyang		Totals	
Hydrocynus	1972	-	-	13	-	NF	NF	33	-	25	-	35	-	29	-	31	-	64	-	230	-
forskalii	1973	-	-	13	-	*	-	38*	-	19	-	37	-	26	-	46	-	111	-	289	-
	1974	-	-	13	-	24	-	24	-	15	-	29	-	27	-	38	-	113	-	284	-
Citharinus[1]	1972	-	-	-	-	NF	NF	-	_35_	-	_30_	-	_15_	-	-	-	-	-	-	-	80
citharus	1973	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1974	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Labeo	1972	49	_15_	-	-	NF	NF	-	_7_	-	_5_	-	_5_	-	-	-	-	-	-	49	_32_
horie	1973	40	_9_	-	-	-	*	-	_35*_	-	_15_	-	_6_	-	-	-	-	-	-	40	_65_
	1974	35	-	-	_10_	-	_104_	-	_85_	-	_35_	-	_27_	-	-	-	-	-	-	35	_261_
Barbus	1972	-	-	-	-	NF	NF	-	-	-	-	-	-	-	-	-	-	-	-	-	-
bynni	1973	-	-	-	-	-	*	-	_3*_	-	_1_	-	-	-	-	-	-	-	-	-	_4_
	1974	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clarias	1972	-	-	-	-	NF	NF	-	-	-	-	-	-	-	-	-	-	1	-	1	-
lazera	1973	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	-
	1974	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	-
Bagrus	1972	24	-	-	-	NF	NF	-	-	5	-	7	-	6	-	6	-	24	-	73	-
bayad	1973	24	-	-	-	-	-	-	-	4	-	8	-	6	-	9	-	42	-	93	-
	1974	21	-	-	-	-	-	-	-	3	-	6	-	6	-	8	-	43	-	87	-
Synodontis	1972	25	-	8	-	NF	NF	20	-	10	-	14	-	12	-	12	-	16	-	116	-
schall	1973	12	-	8	-	*	*	22*	_15*_	7	_2_	15	-	11	-	18	-	27	-	121	_17_
	1974	10	-	8	-	14	_62_	14	_75_	6	_7_	12	_5_	11	-	15	-	28	-	118	_149_
Lates spp.[1]	1972	-	-	-	-	NF	NF	-	_20_	-	_10_	-	_15_	-	-	-	-	-	-	-	_45_
	1973	-	-	-	-	-	*	-	_31*_	-	_6_	-	_15_	-	-	-	-	-	-	-	_52_
	1974	-	-	-	-	-	_28_	-	_8_	-	_4_	-	_10_	-	-	-	-	-	-	-	_50_
Sarothero-	1972	-	_20_	-	-	NF	NF	-	_30_	-	_2_	-	-	-	-	-	-	-	-	-	_52_
don spp.[2]	1973	-	_9_	-	-	-	*	-	_121*_	-	-	-	-	-	-	-	-	-	-	-	_130_
	1974	-	-	-	-	-	_304_	-	_25_	-	_2_	-	-	-	-	-	-	-	-	-	_331_
Total all	1972																			469	_209_
species	1973																			545	_268_
	1974																			525	_791_

* 1973 catches recorded for Kalokol include some fish from the East Shore region. NF = no fishing.

[1] Filleted-dried products.

[2] includes a small proportion of fresh fish exported

TABLE 6.19

Total annual yields of each species of fish in tonnes equivalent fresh weight estimated for each cooperative region for 1972, 1973 and 1974. NF = area not fished during 1972 * = 1973 Kalakol cooperative data include fish from East Shore.

Species	Yr	Kerio	Eliye	East Shore	Kalokol	Namudak	Kataboi	Nachukui	Lowarengak	Todenyang	Total all species
Heterotis	72	5	+	NF	+	+	-	-	+	+	5
niloticus	73	1	+	*	+*	-	-	+	+	1	2
	74	+	-	-	-	+	-	-	1	16	17
Mormyridae	72	-	-	NF	-	-	-	-	-	-	-
	73	-	-	-	-	-	-	-	+	+	+
	74	-	-	-	-	-	-	-	+	1	1
Gymnarchus	72	-	-	NF	-	-	-	-	-	+	+
niloticus	73	-	-	-	-	-	-	-	+	5	5
	74	-	-	-	-	-	-	-	+	6	6
Hydrocynus	72	1	13	NF	34	25	35	29	31	65	233
forskalii	73	1	13	*	39*	19	37	27	48	127	316
	74	2	13	24	24	16	30	28	40	141	318
Citharinus	72	34	19	NF	86	43	36	23	144	281	666
citharus	73	18	11	*	52*	9	7	2	33	279	410
	74	14	7	13	6	2	1	+	3	63	108
Distichodus	72	83	2	NF	44	32	54	65	48	134	480
niloticus	73	20	7	*	15*	18	31	38	35	123	287
	74	6	2	2	1	4	9	14	7	63	108
Labeo	72	340	13	NF	59	42	48	42	16	26	586
horie	73	237	19	*	72*	44	108	87	101	124	794
	74	177	26	120	98	60	141	95	86	228	1034
Barbus	72	1	+	NF	3	2	2	6	29	43	87
bynni	73	4	+	*	5*	2	13	56	99	134	315
	74	2	+	1	1	1	10	27	145	254	442
Clarias	72	7	+	NF	+	-	+	+	+	1	9
lazera	73	20	1	*	5*	+	+	+	+	4	31
	74	10	1	9	2	1	+	+	1	20	42
Bagrus	72	25	+	NF	2	10	8	6	7	24	83
bayad	73	29	1	*	16*	14	14	9	12	44	139
	74	26	2	74	19	27	23	18	19	55	262
Bagrus	72	1	1	NF	+	+	+	-	+	+	2
docmac	73	1	1	*	1*	+	+	+	+	+	3
	74	1	1	1	1	-	1	-	+	+	6
Synodontis	72	25	8	NF	19	10	14	12	12	16	116
schall	73	12	8	*	37*	9	15	11	18	27	138
	74	11	8	74	89	13	17	11	15	28	265
Heterobr-	72	-	-	NF	-	-	-	-	-	-	-
anchus sp	73	-	-	-	-	-	-	-	+	1	1
	74	-	-	-	-	-	-	-	-	+	+
Lates spp.	72	139	37	NF	42	16	22	18	19	90	382
	73	107	40	*	74*	14	25	23	32	121	435
	74	111	44	102	30	15	29	26	38	112	508
Sarothero-	72	73	25	NF	31	2	+	+	+	+	131
don spp.	73	53	29	*	133*	2	+	+	+	+	217
	74	78	30	306	27	2	+	+	+	3	447
All species	72	734	137	NF	320	181	218	201	307	681	2779
	73	502	131	*	449*	132	250	253	379	993	3089
	74	439	135	725	297	142	260	220	357	991	3565

The totals include very small quantities of *Alestes* spp.

TABLE 6.20

Estimates of annual yield per area (in tonnes fresh fish/km^2/year) for the various cooperative regions. The area exploited in km^2 is given in brackets. NF = not fished, * = includes East Shore areas during 1973.

Year	Kerio	Eliye	East	Kalokol	Namudak	Kataboi	Nachukui	Lowarengak	Todenyang	Total
1972	4.6	1.4	NF	4.1	4.1	2.2	2.0	3.1	6.8	3.54
	(160)	(104)		(78)	(44)	(100)	(100)	(100)	(100)	(786)
1973	2.8	1.3	*	5.0*	3.0	2.2	2.1	3.5	5.4	3.28
	(179)	(104)		(90)	(44)	(116)	(118)	(109)	(183)	(943)
1974	2.3	1.3	24.2	2.8	2.8	2.2	1.8	3.1	5.2	3.58
	(190)	(104)	(30)	(78)	(50)	(120)	(120)	(115)	(190)	(997)

TABLE 6.21

An analysis of the fish production of Lake Turkana on the basis of processing method for the years 1972, 1973 and 1974. Total annual production in tonnes (fresh weight equivalent) has been estimated for each product. Each value is expressed as a percentage of the total annual yield in brackets.

Year	Salted-dried	Filleted-dried	Smoked	Fresh (subsistance)	Total co-operative traffic	Total yield
1972	1980 (71)	246 (9)	84 (3)	469 (17)	2101 (76)	2779
1973	2168 (70)	160 (5)	216 (7)	545 (18)	2276 (74)	3089
1974	2150 (60)	150 (4)	741 (21)	525 (15)	2250 (63)	3565

TABLE 6.22

Weekly values of F (= total number of different fishermen visiting a cooperative per week) estimated for each cooperative region during the calibration period, November 1973 to February 1974.

Week No:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Todenyang:	482	549	501	495	559	591	523	532	519	506	302	447	492	345	482
Lowarengak:	231	262	237	238	220	238	217	190	160	211	185	142	172	197	182
*Nachukui:	131	154	158	152	154	148	138	108	107	131	107	112	120	88	94
*Kataboi:	173	186	182	175	143	166	145	127	147	150	151	120	145	135	130
Namudak:	89	78	71	56	58	74	41	52	50	58	50	75	84	71	54
Kalokol (only):	90	80	77	81	51	108	63	74	97	80	127	48	53	16	52
East Shore (through Kalokol):	84	51	85	63	44	124	43	99	90	90	107	78	55	11	97
Kerio:	178	148	150	152	132	147	122	115	147	139	102	117	130	131	113

* computed from values of V using method described in Appendix 6 IV.I

TABLE 6.23

Weekly values of F (= total number of different fishermen visiting a cooperative per week) estimated for the Kalokol cooperative during the calibration period, November 1973 to February 1974. The first line shows values of F for the combined data for all fishing regions serving Kalokol (Kalokol (only), Namudak and East Shore (through Kalokol)). In the second line separate values of F for each of the three fishing regions (Table 6.22) have been summed. The percentage overlap between the two values of F is shown in the final line.

Week No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Kalakol combined F	207	177	200	180	135	247	137	186	198	190	228	185	174	95	189
Sum of F for separate regions	263	209	233	200	153	306	147	225	237	228	284	201	192	98	203
% overlap	24	15	14	10	12	19	7	17	17	17	20	8	9	3	7

TABLE 6.24

Comparison of $\bar{F}$ (derived from the values of F in Tables 6.22 and 6.23) with F_{tot} for each cooperative region during the calibration period November 1973 to February 1974.

Region	$\bar{F}$ (mean of F values)	F_{tot}	$\bar{F}$ x $100/F_{tot}$
Todenyang	488	1035	47%
Lowarengak	205	473	43%
Nachukui	127	277*	-
Kataboi	152	323*	-
Kerio	135	280	48%
Namudak	64	277	23%
Kalokol (only)	73	369	20%
East Shore (through Kalokol)	75	364	21%
Kalokol Coop. Branch	182	488	37%

*these are estimated on a basis of $\bar{F}/F_{tot}$ = 47%.

TABLE 6.25

Values of '$\bar{F}$' and F_{max} for 1972, 1973 and 1974.

Region	1972 (part)[1]		1973		1974 [2]	
	$\bar{F}$	(F_{max})	$\bar{F}$	(F_{max})	$\bar{F}$	(F_{max})
Todenyang	220	(361)	440	(620)	417	(632)
Lowarengak	119	(169)	155	(250)	158	(210)
Nachukui	104	(158)	112	(145)	107	(147)
Kataboi	136	(191)	132	(202)	131	(161)
Namudak	90	(137)	59	(103)	47	(85)
Kalokol only	106	(180)	72[1]	(127)[1]	55	(127)
East Shore (Kalokol)	-	-	82[3]	(124)[2]	85	(130)
Eliye	50	(70)	40	(70)	40	(70)
Kerio	219	(332)	178	(262)	129	(227)

[1] based on 35 weeks

[2] based on 8 weeks

TABLE 6.26

Estimates of E (total fishing effort) for each cooperative region for 1972, 1973 and 1974. Combined values of E have been used to provide an estimate of fishing intensity in E/km^2 in the last line.

Region	1972	1973	1974
Todenyang	237	463	441
Lowarengak	125	167	164
Nachukui	110	116	111
Kataboi	143	141	134
Namudak	96	65	51
Kalokol (only)	115	79)	68
		)114*	
East Shore (through Kalokol)	-	81)	85
Eliye	52	44	43
Kerio	233	189	140
Total	1100	1288	1237
Fishing Intensity (E/km^2)	1.40	1.37	1.24

*combined value, for use with combined yields

TABLE 6.27

Numbers of fishing boats counted in each cooperative region during two censuses, the first in April 1972 by boat and the second in October 1973 by aircraft.

Buying Point	1st Survey (by boat, 25-28 April '72)	2nd Survey (aerial, 1 Oct '73)
Todenyang	24	38
Lowarengak	10	12
Nachukui	8	9
Kataboi	16	12
Namudak	19	8
Kalokol (+ E. Shore-2nd Survey)	12	17
Eliye	6	4
Kerio	11	16
Totals	106	117

TABLE 6.28

Mean number of nets used per fisherman

Date	Region	No. fishermen (sample)	Mean no. nets/ fisherman ± s.dev
Oct 73	Kataboi	44	2.55 ± 0.42
Oct 73	Namudak	28	2.98 ± 0.54
Dec 73	Kalokol	19	2.42 ± 0.84

Weighted mean for all samples = 2.65 nets

TABLE 6.29

Showing the percentage frequency of nets of each mesh size in samples measured in various cooperative regions on the dates indicated. The mean stretched mesh size of each sample is shown in both inches and cm.

Date	Region	Sample size	Stretched mesh size (inches)															Mean stretched mesh	
			2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	inches	cm
14.3.73	Todenyang	108	-	-	-	1.9	-	3.7	3.7	13.0	10.2	17.6	20.4	21.3	5.6	2.8	-	7.10	18.0
13.9.73	Todenyang	21	-	-	-	-	-	4.8	4.8	4.8	9.5	19.0	23.8	28.6	-	4.8	-	7.28	18.5
6.2.75	Todenyang	134	-	-	-	-	2.2	14.2	32.1	24.6	10.4	7.5	2.2	6.0	-	-	0.7	6.03	15.3
15.3.73	Lowarengak	17	-	-	-	-	5.9	5.9	11.8	17.8	5.9	11.8	29.4	11.8	-	-	-	6.88	17.0
7.2.75	Lowarengak	22	-	-	-	-	4.5	9.1	36.4	40.9	9.1	-	-	-	-	-	-	5.72	14.5
16.3.73	Nachukui	23	-	-	-	-	4.3	4.3	4.3	17.4	8.7	8.7	17.4	21.7	8.7	-	-	7.00	17.8
24.4.73) 27.8.73)	Kataboi	9	-	-	11.1	-	22.2	22.2	-	-	-	22.2	22.2	-	-	-	-	5.72	14.5
18.3.75	Kataboi	203	-	-	-	5.4	14.3	21.1	35.5	10.8	8.4	-	4.4	-	-	-	-	5.40	13.7
28.8.73	Namudak	19	-	-	-	-	10.5	15.8	15.8	10.5	5.3	5.3	15.8	15.8	-	-	5.3	6.42	16.3
15.3.75	Namudak	209	0.5	0.5	4.8	12.0	23.0	24.4	24.4	2.4	-	1.0	5.3	1.0	0.5	0.5	-	5.03	12.8
24.4.73	Kalokol	59	-	-	3.4	8.5	11.9	10.2	10.2	8.5	5.1	10.2	11.9	11.9	3.4	5.1	-	6.19	15.7
3.2.75	Kalokol (Ferguson's Gulf)	162	-	-	19.8	38.3	38.3	3.1	0.6	-	-	-	-	-	-	-	-	4.13	10.5
13.8.73	Kerio	139	-	0.7	2.2	10.1	25.9	21.6	6.5	4.3	2.9	5.8	7.2	7.2	0.7	-	-	5.25	13.3

TABLE 6.30

Catch per effort in the Turkana inshore fisheries expressed in terms of kg fresh-weight/full-time fisherman/week for 1972, 1973 and 1974. Estimated values are given species by species for each cooperative region with a combined value for the entire fishery in the final column.

Species	Yr	Kerio	Eliye	East Shore	Kalokol	Namudak	Kataboi	Nachukui	Lowarengak	Todenyang	All regions
Heterotis niloticus	72	0.43	0.07	NF	+	+	+	-	+	+	0.09
	73	0.08	0.04	*	+*	-	-	+	+	0.03	0.03
	74	0.03	-	-	-	+	-	-	0.11	0.69	0.26
Hydrocynus forskalii	72	0.07	4.9	NF	5.6	5.0	4.7	5.1	4.8	5.3	4.0
	73	0.09	5.8	*	6.5*	5.6	5.1	4.5	5.6	5.3	4.7
	74	0.26	5.9	5.5	6.8	6.0	4.3	4.8	4.8	6.1	4.9
Citharinus citharus	72	2.78	7.0	NF	14.46	8.53	4.84	4.04	22.18	22.79	11.64
	73	1.82	4.7	*	8.70*	2.69	0.94	0.38	3.77	11.59	6.12
	74	1.91	3.1	2.87	1.70	0.64	0.10	0.05	0.38	2.74	1.68
Distichodus niloticus	72	6.85	7.4	NF	7.32	6.39	7.24	11.35	7.43	10.88	8.39
	73	2.07	3.0	*	2.51	5.38	4.26	6.25	4.00	5.12	4.29
	74	0.88	0.9	0.36	0.31	1.47	1.23	2.46	0.83	2.75	1.68
Labeo horie	72	28.04	4.8	NF	9.82	8.47	6.41	7.43	2.45	2.11	10.24
	73	24.14	8.4	*	12.21*	13.20	14.73	14.37	11.65	5.16	11.85
	74	24.42	11.6	27.19	27.80	22.70	20.24	16.56	10.15	9.96	16.07
Barbus bynni	72	0.12	0.1	NF	0.52	0.34	0.26	1.05	4.48	3.50	1.52
	73	0.40	0.2	*	0.89	0.62	1.83	9.30	11.42	5.59	4.70
	74	0.34	0.1	0.18	0.23	0.34	1.49	1.63	17.03	11.09	6.87
Clarias lazera	72	0.61	0.2	NF	0.02	-	+	+	+	0.11	0.16
	73	2.06	0.6	*	0.86*	0.06	+	+	0.02	0.18	0.47
	74	1.33	0.4	1.97	0.68	0.26	+	+	0.07	0.86	0.65
Bagrus bayad	72	2.06	0.07	NF	0.38	2.04	1.04	1.08	1.02	1.97	1.45
	73	2.94	0.4	*	2.65*	4.02	1.85	1.56	1.43	1.35	2.08
	74	3.52	0.9	16.65	5.32	10.11	3.30	3.17	2.19	2.39	4.07
Bagrus docmac	72	0.05	0.4	NF	0.03	+	+	-	+	+	0.03
	73	0.06	0.5	*	0.17*	0.09	0.03	+	+	0.01	0.05
	74	0.21	0.7	0.23	0.17	0.08	0.10	-	0.02	0.01	0.09
Synodontis schall	72	2.1	2.8	NF	3.3	2.0	1.9	2.0	1.9	1.3	2.0
	73	1.3	3.3	*	6.3*	2.8	2.0	1.8	2.1	1.1	2.1
	74	1.5	3.4	16.8	25.1	5.0	2.4	1.9	1.8	1.2	4.1
Lates spp.	72	11.5	13.7	NF	7.0	3.1	2.9	3.1	3.0	7.3	6.7
	73	10.9	17.4	*	12.5*	4.0	3.4	3.8	3.7	5.0	6.5
	74	15.3	19.7	23.1	8.5	5.8	4.1	4.5	4.5	4.9	7.9
Sarotherodon spp.	72	6.0	9.2	NF	5.2	0.4	0.01	+	+	+	2.29
	73	5.4	12.7	*	22.5*	0.5	0.04	+	0.01	0.02	3.24
	74	10.7	13.4	69.2	7.6	0.9	0.06	0.02	0.02	0.15	6.95
Total/region (all species)	72	60.6	51	NF	53.5	36.3	29.3	35.1	47.2	55.3	48.6
	73	51.1	57	*	75.7	39.1	34.1	41.9	43.6	41.2	46.1
	74	60.3	60	164.0	84.0	53.5	37.3	38.1	41.9	43.2	55.4

NF = no fish of East Shore origin marketed through Kalokol during 1972.

* = 1973 data includes fish of East Shore origin marketed through Kalokol but not recorded separately.

TABLE 6.31

Experimental gillnet specifications

Stretched mesh (inches)	(cm)	Twine rating	No. of meshes in depth
2	5.08	210/6	88
3	7.62	210/6	58
4	10.16	210/9	44
5	12.70	210/12	35
6	15.24	210/15	29
7	17.78	210/18	25
8	20.32	210/21	20
9	22.86	210/21	17
10	25.40	210/21	15

TABLE 6.32

Summary of experimental gillnet sampling.

Area	Months fished	No. of settings	No. of net settings[1]	Mesh sizes used (inches)
Kerio	Mar-Nov 1973	110	162	4½*, 5, 6, 7, 8
Kalokol (inc. F. Gulf)	Nov 1972, Jan-Mar 1973 May, Aug, Sept 1973	27	67	4, 5, 6, 7, 8
Todenyang (inshore)	Jul-Nov 1973	77	207	5, 6, 7, 8
Todenyang (offshore)[2]	May, Jun 1973	5	20	4, 5, 6, 7, 8, 9
Koobi Fora[2]	Dec 1973	8	48	4, 5, 6, 7, 8, 9
	Totals	227	504	

*Non-standard net.

[1] Total of number of settings for each net combined.

[2] These areas are outside the area of exploitation shown in Figure 6.2b.

TABLE 6.33

Results of experimental gillnetting in Kerio Bay during the period March to November 1973. The mean monthly catch per effort for each mesh size is given in kg fresh fish/standard net/setting. The number of settings appears in brackets below the standard deviation for each value.

Month	Depth (m) at station	Nets at surface (S) and/or bottom (B)	Stretched mesh size (inches)				
			4½	5	6	7	8
1973							
Mar	6	S	-	-	-	-	4.69 ±3.17 (11)
Apr	6	S	-	-	-	-	4.93 ±6.77 (21)
May	6	S	-	-	-	-	1.90 ±2.04 (23)
May	4	S & B*	-	6.05 ±4.62 (10)	-	2.30 ±3.04 (20)	-
Jun	6	S	-	-	-	-	1.16 ±1.59 (13)
Jun	4	S & B*	3.16 ±0.53 (7)	-	-	3.80 ±3.35 (11)	-
Jul	6	S	-	-	-	-	3.17 ±3.68 (6)
Jul	4	S & B*	4.56 ±1.89 (7)	-	-	4.52 ±3.79 (6)	
Aug	4	S & B*	-	15.66 (1)	14.95 (1)	-	-
Sep	4	S & B*	-	2.34 ±0.60 (3)	2.28 (1)	-	9.67 ±7.39 (4)
Oct	6	S	-	-	-	-	6.61 ±5.03 (12)
Oct	4	S & B*	-	2.80 ±1.17 (4)	-	-	-
Nov	6	S	-	-	-	-	6.87 (1)

* nets extending from surface to bottom.

TABLE 6.34

Results of experimental gillnetting at Kalokol during the period November 1972 to May 1973. The mean monthly catch per effort for each mesh size is given in kg fresh fish/standard net/setting. The number of settings appears below the standard deviation for each value.

Month	Depth (m)* at station	Nets at surface (S) or bottom (B)	Stretched mesh size (inches)				
			4	5	6	7	8
1972							
Nov	9-10	S	8.6 (1)	-	-	-	6.0 (1)
1973							
Jan	8-9	S	-	3.06 ±2.65 (3)	1.43 ±0.56 (3)	3.18 ±2.85 (3)	8.42 ±6.40 (3)
Feb	8	S	-	3.04 ±1.36 (4)	2.93 ±3.01 (4)	4.15 ±4.11 (4)	3.35 ±2.39 (4)
May	8	S	13.0 (1)	5.13 ±0.79 (3)	2.61 ±1.42 (2)	1.74 ±2.45 (2)	3.70 ±5.23 (2)
May	8	B	-	4.18 ±3.11 (2)	4.38 ±3.61 (2)	0.11 ±0.15 (2)	0 (2)

* All the above were fished at the same station, about 2 km off the R. Kalokol Delta. The changing depth is due to the lake level dropping.

TABLE 6.35

Results of experimental gillnetting in Ferguson's Gulf during the period January to September 1973. The mean monthly catch per effort for each mesh size is given in kg fresh fish/standard net/setting. The number of settings appears in brackets below the standard deviation for each value.

Month	Depth (m) at station*	Nets at surface (s) and/or bottom (B)	Stretched mesh size (inches		
			5	7	8
1973					
Jan	4	S & B	1.81 ±1.49 (3)	-	0.90 ±1.56 (3)
Mar	4	S & B	-	0 (2)	0 (2)
Aug	4	S & B	1.91 ±1.55 (5)	-	-
Sep	4	S & B	2.63 ±1.04 (4)	-	-

* About ½ km west of Ferguson's Gulf Meteorological Station.

TABLE 6.36

Results of experimental gillnetting in the Todenyang inshore fishing area during the period July to November 1973.* The mean monthly catch per effort for each mesh size is given in kg fresh fish/standard net/setting. The number of settings appears in brackets below the standard deviation for each value.

Month	Stretched mesh size (inches)			
	5	6	7	8
1973				
Jul	1	-	3.73 ±1.32 (6)	-
Aug	4.87 ±2.57 (3)	-	1.59 ±1.12 (4)	-
Sep	5.65 ±4.16 (23)	4.33 ±3.83 (31)	3.82 ±2.54 (31)	-
Oct	4.31 ±3.32 (13)	2.51 ±4.77 (8)	5.18 ±2.42 (3)	3.58 ±2.82 (14)
Nov	3.01 ±1.73 (17)	3.90 +2.64 (18)	2.02 ±1.55 (18)	0.83 ±1.12 (18)

*Nets fished at 3-4 m depth and 2-4 km east of Todenyang. Therefore all nets from surface to bottom.

TABLE 6.37

Results of experimental gillnetting in the Todenyang offshore fishing area during the months of May and June 1973. The mean monthly catch per effort for each mesh size is given in kg fresh fish/standard net/setting. The number of settings appears in brackets below the standard deviation for each value.

Month	Depth (m) at station	Nets at surface (S) or bottom (B)	Stretched mesh size (inches)					
			4	5	6	7	8	9
1973								
May	8 (~ 10 km offshore)	B	-	-	-	26.95 ±5.90 (2)	18.21 ± 9.68 (2)	-
Jun	5 (~ 6 km offshore)	B	52.5 (1)	15.64 ±7.38 (3)	14.27 ±4.18 (3)	14.35 ±3.89 (3)	36.96 ±10.15 (3)	30.60 ±12.69 (3)

TABLE 6.38

Experimental gillnets: combined results from all months for each area showing unweighted mean catch per effort in kg fresh fish per setting of standard net. The standard deviation appears below each value together with the number of settings in brackets.

Area	Stretched mesh size (inches)						
	4	4½	5	6	7	8	9
Kerio Bay	-	3.86 ±1.52 (14)	5.24 ±4.61 (18)	7.29 ±7.58 (2)	3.11 ± 3.29 (37)	3.93 ± 4.83 (91)	-
Kalokol (inc. F. Gulf)	10.8 ± 3.1 (2)	-	2.94 ±1.80 (24)	2.72 ±2.31 (11)	2.29 ± 3.02 (13)	3.22 ± 4.17 (17)	-
Todenyang (inshore)	-	-	4.50 ±3.42 (56)	3.94 ±3.63 (57)	3.21 ± 2.29 (62)	2.03 ± 2.44 (32)	-
Todenyang (offshore)	52.5 (1)	-	15.64 ±7.38 (3)	14.27 ±4.18 (3)	19.39 ± 7.99 (5)	29.46 ±13.43 (5)	30.60 ±12.69 (3)
Koobi Foora (10 m depth)	23.89 ±12.40 (8)	-	10.55 ±4.59 (8)	11.98 ±8.01 (8)	12.68 ±10.13 (8)	13.45 ± 9.27 (8)	19.59 ±25.57 (8)

TABLE 6.39

The effect of wind conditions on catch per effort (expressed as standard measure - see text). Data for a graded fleet of nets set on eight nights at Koobi Fora during December 1973 are arranged in order of increasingly severe wind conditions. Results from all six mesh sizes have been combined in the summary below.

Wind rating			Stretched mesh size (inches)					
Night	Day	Combined	4	5	6	7	8	9
0	0	0	0.72	0.10	0.67	0	0.50	0
0	0	0	0.88	0.76	0.20	0.31	0.39	0.19
0	1	1	0.67	1.38	0.18	0.38	1.11	3.94
0	1	1	1.97	1.21	0.73	0.76	0	0.52
0	2	2	0.52	1.36	1.10	1.72	2.12	1.32
1	2	3	1.20	0.81	1.90	1.81	1.23	0
1	2	3	0.53	1.30	1.40	0.85	1.62	1.41
2	1	3	1.51	1.08	1.81	2.16	1.04	0.62

Summary:

Combined wind rating	Mean	Variance	No. of samples
0 (calm throughout)	0.39	0.10	12
1 (strong during day)	1.07	1.11	12
2 (very strong during day)	1.36	0.30	6
3 (strong to very strong throughout)	1.24	0.30	18

TABLE 6.40

The effect of wind conditions on catch per effort. Results from experimental gillnets set at Todenyang during the period July to November 1973 have been grouped according to prevalent wind conditions. Mean catch per effort (kg fresh fish/standard net/setting) for each wind rating is shown together with the standard deviation followed by the number of settings in brackets. In the lower section of the table results from all mesh sizes have been combined in standard measure (see text).

Weather rating	Stretched mesh size (inches)			
	5	6	7	8
0	3.85 ± 6.40(15)	3.07 ± 11.70(17)	2.82 ± 4.75(18)	1.03 ± 1.56(6)
1	4.21 ± 6.76(18)	3.90 ± 13.47(19)	3.76 ± 6.05(25)	1.63 ± 3.80(10)
2	5.18 ± 21.90(20)	5.10 ± 15.44(17)	2.76 ± 5.48(15)	2.73 ± 9.90(14)

Summary in standard measure:

Weather rating	Mean catch/effort	Variance	No. of samples
0 (calm throughout)	0.82	0.51	56
1 (windy)	1.03	0.66	72
2 (very windy)	1.18	1.23	66
3 (1 and 2 combined)	1.11	0.93	138

TABLE 6.41

Estimates of mean catch per effort for individual species of fish in kg fresh fish/standard net/setting derived from experimental gillnet data for the Kerio area. Data for various mesh sizes are included and the number of fish/standard net/setting is given in brackets.

Species	Stretched mesh size (inches)				
	4.5	5	6	7	8
Hydrocynus	-	-	-	-	+ (+)
Citharinus	-	0.15(0.07)	-	0.09(0.04)	0.09(0.04)
Distichodus	-	-	2.28(0.5)	0.03(0.01)	0.17(0.03)
Labeo	3.65(2.46)	4.23(2.41)	2.48(1.5)	0.07(0.03)	0.01(+)
Barbus bynni	0.21(0.14)	-	-	-	-
Clarias	-	0.05(0.04)	-	0.15(0.03)	0.01(+)
Bagrus bayad	-	0.54(0.54)	-	0.02(0.01)	0.03(+)
Synodontis schall	-	0.08(0.13)	0.25(0.5)	-	+ (+)
Lates niloticus	-	0.20(0.04)	2.28(0.5)	2.75(0.45)	3.60(0.41)
Lates longispinis	-	-	-	-	-
Sarotherodon spp.	-	-	-	-	0.02(0.01)

TABLE 6.42

Estimates of mean catch per effort for individual species of fish in kg fresh fish/standard net/setting derived from experimental gillnet data for the Kalokol area (including Ferguson's Gulf). Data for various mesh sizes are included and the number of fish/standard net/setting is given in brackets.

Species	Stretched mesh size (inches)				
	4	5	6	7	8
Hydrocynus	3.89 (2.75)	0.65(0.36)	-	-	-
Citharinus	-	0.32(0.20)	1.21(0.55)	1.33(0.58)	1.87(1.21)
Distichodus	-	+	-	-	-
Labeo	1.39 (1.00)	1.21(0.59)	0.77(0.23)	-	-
Barbus bynni	-	0.05(0.05)	-	-	-
Bagrus bayad	-	0.04(0.05)	-	-	-
Synodontis schall	5.25(12.50)	0.64(1.58)	0.14(0.41)	0.06(0.19)	-
Lates niloticus	-	0.03(0.02)	0.60(0.14)	0.89(0.15)	1.33(0.15)
Lates longispinis	0.25 (0.25)	-	-	-	0.02(0.03)

TABLE 6.43

Estimates of mean catch per effort for individual species of fish in kg fresh fish/standard net/setting derived from experimental gillnet data for the inshore and offshore fishing areas at Todenyang. Data for various mesh sizes are included and the number of fish/standard net/setting is given in brackets.

Species	Stretched mesh size (inches)				
	5	6	7	8	9
Hydrocynus	1.09(0.50)	0.68(0.30)	0.36(0.14)	0.11(0.05)	-
Citharinus	0.09(0.03)	0.29(0.11)	0.60(0.21)	1.19(0.44)	1.18(0.33)
Distichodus	0.12(0.05)	0.22(0.05)	0.29(0.07)	0.22(0.04)	3.25(0.50)
Labeo	1.18(0.55)	1.04(0.38)	0.26(0.07)	0.19(0.04)	-
Barbus bynni	1.13(0.71)	0.90(0.46)	1.38(0.44)	1.00(0.30)	1.48(0.33)
Clarias	0.04(0.02)	0.14(0.02)	-	0.17(0.02)	-
Bagrus bayad	0.22(0.24)	0.13(0.10)	0.06(0.12)	0.06(0.17)	
Synodontis schall	0.64(1.27)	0.16(0.41)	0.05(0.11)	0.06(0.16)	0.06(0.17)
Lates niloticus	0.83(0.52)	1.19(0.51)	1.15(0.27)	2.71(0.40)	24.58(3.33)
Lates longispinis	0.06(0.07)	0.02(0.02)	0.01(0.01)	0.01(0.03)	-

TABLE 6.44

Estimates of mean catch per effort for individual species of fish in kg fresh fish/standard net/setting derived from experiemntal gillnet data at Koobi Fora. Data for various mesh sizes are included and the number of fish/standard net/setting is given in brackets.

Species	Stretched mesh size (inches)					
	4	5	6	7	8	9
Hydrocynus	3.15 (2.13)	1.41(0.63)	0.58(0.25)	-	-	-
Labeo	0.38 (0.25)	1.32(0.63)	-	-	-	-
B. bynni	9.59(12.38)	4.87(4.75)	5.83(2.88)	4.42(1.50)	1.94(0.63)	1.04(0.13)
B. bayad	5.00 (3.88)	0.68(0.38)	1.17(0.50)	0.42(0.25)	-	-
B. docmac	-	-	0.64(0.13)	-	-	-
S. schall	1.09 (2.63)	0.68(1.13)	0.16(0.50)	0.08(0.13)	-	-
Schilbe	0.03 (0.13)	-	-	-	-	-
Lates n.	3.45 (0.50)	0.57(0.25)	3.20(1.25)	7.75(1.63)	11.51(1.88)	18.49(1.38)
Lates l.	1.20 (2.38)	1.17(1.63)	0.42(0.38)	0.01(0.13)	-	0.06(0.13)

TABLE 6.45

Results of analysis of gillnet selection by Holt's method

Mesh size (inches)	Species																				
	Labeo horie			Hydrocynus			Barbus bynni			Distichodus			Lates niloticus			Lates longispinis			Synodontis schall		
	Σl	$\bar{l}$	s.d.	Σl	$\bar{l}$	s.d.	Σl	$\bar{l}$	s.d.	Σl	$\bar{l}$	s.d.	Σl	$\bar{l}$	s.d.	Σl	$\bar{l}$	s.d.	Σl	$\bar{l}$	s.d.
2		25.1			29.9			17.8			22.1			20.2			24.2			16.4	
2 and 3	59.3		5.1	77.1		6.2	46.4		5.0	-		-	-		-	67.0		8.6	42.6		5.8
3		37.7			44.9			26.7			33.1			30.3			36.3			24.6	
3 and 4	91.3		4.7	111.1		6.6	69.0		4.4	84.1		6.4	-		-	81.7		7.2	55.3		6.0
4		50.2			59.9			35.6			44.2			40.4			48.4			32.8	
4 and 5	113.9		6.0	135.0		7.7	92.3		5.1	146.5*		10.1	-		-	106.0		6.2	-		-
5		62.8			74.9			44.5			55.2			50.5			60.5			-	
5 and 6	136.2		8.0	153.3		11.9	96.7		8.9	108.4		12.9	94.4		14.1	-		-	-		-
6		75.3			89.8			53.4			66.2			60.6			-			-	
6 and 7	164.3		10.6	197.1		15.6	109.5		6.3	149.9		11.7	144.7		10.0	-		-	-		-
7		87.9			104.8			62.3			77.3			70.7			-			-	
7 and 8	-		-	-		-	119.6		7.8	115.8*		28.8	154.9		10.1	-		-	-		-
8		-			-			71.2			88.3			80.8			-			-	
Coeff. of regression in cm (TL or FL)/mesh size in inches	12.55(TL)			14.97(TL)			8.9(FL)			11.0(TL)			10.1(TL)			12.1(TL)			8.2(FL)		
Mean coefficient of variation	12.4			14.2			15.0			21.8			17.8			18.9			24.6		

Legend:
Σl = sum of mean selection lengths for pair of meshes (cm).
$\bar{l}$ = calculated mean selection length (cm).
s.d. = standard deviation of selection curves (cm).

*Obtained from poor correlations

TABLE 6.46

Todenyang: a comparison of catch per effort (in kg/F/week) derived from cooperative data with values for the equivalent week estimated from experimental gillnet data.

Equivalent week beginning	No. of settings of exp. nets	No. of settings per week (extra-polated where necessary)	Equivalent catch per effort of experimental nets	Commercial catch/effort from Cooperatives
20-7-73	6	7	39.2	21.7
6-8-73	3	7	19.6	28.0
20-8-73	1	7	27.7	37.5
27-8-73	2	7	30.8	23.0
3-9-73	4	7	59.7	36.7
10-9-73	6	6	58.6	40.6
17-9-73	7	10	56.0	50.0
24-9-73	9	9	55.7	32.0
1-10-73	7	7	50.8	48.1
15-10-73	6	8	73.7	45.6
22-10-73	2	6	52.3	36.7
29-10-73	6	8	28.9	31.9
5-11-73	1	7	30.1	26.1
12-11-73	1	7	37.8	30.4
19-11-73	6	9	23.8	42.7
26-11-73	7	9	29.1	35.6
3-12-73	3	7	19.3	30.6
Means		1.08 sets/day	40.77	35.13

TABLE 6.47

Todenyang: a comparison of catch per effort (in kg/F/week) for individual species of fish, derived from cooperative data for the period July - December 1973 (see Table 6.46), with the corresponding results from experimental gillnets.

Species	Cooperative: mean catch per effort	Experimental: mean catch per effort
Citharinus	14.5	12.6
Labeo	4.7	3.0
Lates spp.	4.5	8.3
Distichodus	4.4	2.3
Barbus bynni	4.3	6.2
Hydrocynus	1.6	5.3
Bagrus bayad	0.2	1.6
Clarias	0.2	0.3
Synodontis schall	-	0.9
Others	0.8	+

TABLE 6.48

Kerio: a comparison of catch per effort (in kg/F/week) for individual species of fish derived from cooperative data for the period March - November 1973 with the corresponding results for experimental gillnets.

Species	Cooperative: mean catch per effort	Experimental: mean catch per effort
Labeo	21.6	31.9
Lates spp.	10.5	9.7
Sarotherodon spp.	5.0	+
Clarias	2.0	0.4
Distichodus	1.1	3.0
Citharinus	0.7	0.8
Heterotis	0.4	-
Bagrus bayad	0.4	2.2
Barbus bynni	0.2	0.7
Synodontis schall	-	0.9
Others	0.1	-

TABLE 6.49

Kalokol: a comparison of catch per effort (in kg/F/week) for individual species of fish derived from cooperative data obtained during the period January - May 1973, with the corresponding results for experimental gillnets.

Species	Cooperative: mean catch per effort	Experimental: mean catch per effort
Citharinus	12.4	18.4
Labeo	5.3	6.0
Distichodus	3.7	-
Lates spp.	2.5	8.5
Bagrus bayad	0.6	0.2
Hydrocynus	0.2	3.7
Barbus bynni	0.1	0.1
Synodontis schall	-	2.8
Others	0.2	-

TABLE 6.50

Summary of previous records of catch per effort relating to 5 and 8 inch gillnets in Lake Turkana.

Date	Net (inches)	Region	Number of sets	Mean catch/effort (kg/standard net-set) ± s.d.	Reference
6, 7 Nov 1963	8 (Turkana)	> 100 yards offshore at Longech Spit	13	52.7 ± 17.4	MANN (1964), Table 2
2-17 Nov 1963	8 (Experimental)	100 yards offshore	11	57.7 ± 23.8	MANN (1964), Table 3
23, 24 Oct 1963	5 (Experimental)	< 100 yards offshore at Longech Spit	2	31.1 ± 12.4	MANN (1964), Table 1
1962	8	Kalokol	?	111	Kenya Fisheries Dept annual report, 1962
1962	5	"	?	27.1	
Jul 1969	8	Eliye	2	2.5	Fisheries Dept (internal report)
Feb, Mar and Apr 1969	8 (Turkana)	Lowarengak (inc. Todenyang)	147 nets/month	13.7	Internal report from Fr. Foley, Catholic Mission.

APPENDIX 6.I

A checklist of fish caught by Turkana fishermen.

	Turkana name	Swahili name
Polypterus bichir	nagiri	
Polypterus senegalus	nagiri	
Mormyridae (most or all Mormyrus spp.)	lomakale*	
"	mkale	
"	lochomilo	
Gymnarchus niloticus	lowayarame	
Heterotis niloticus	dese	
Alestes baremose	lelete*	
Alestes baremose	dorobela	
Hydrocynus forskalii	lokel	
Citharinus citharus	gage	sahani
Distichodus niloticus	golo	
Labeo horie	chubule	ningu
Barbus bynni	momwara*	
Barbus bynni	nabile	
Clarias lazera	kopito	
Heterobranchus longifilis[1]	labe	
Schilbe uranoscopus	naili	
Bagrus bayad	loruk	
Bagrus docmac	lisi	
Synodontis schall	tiri	
Malapterurus electricus	lasali	
Lates niloticus	iji*	mfuta
Lates longispinis	iji	
Sarotherodon niloticus	kokine	ngege*
Sarotherodon galilaeus	kokine	ngege*
Tetraodon fahaka	lokwi	

---

[1] Species not confirmed * name mostly used by Turkana.

The vernacular names are spelt phonetically.

APPENDIX 6.II

Relationship between important parameters of major commercial fishes.

6.II.1. Weight/Length Relationships

general formula: $w = a_o l^{a_1}$ (where w = weight in gms and l = fork length or total length in cm)*

Species	a_o	a_1	Sample size	FL or TL	Length Range of Calibration
Hydrocynus	4.36×10^{-3}	3.086	145	TL	26-68
Citharinus	7.36×10^{-3}	3.156	68	TL	35-63
Distichodus	1.36×10^{-3}	3.519	57	TL	38-83
Labeo	7.24×10^{-3}	3.073	105	TL	17-78
Barbus bynni[3]	2.78×10^{-3}	3.444	69	FL	28-69
Clarias lazera[1]	2.06×10^{-3}	3.311	12	TL	50-80
Bagrus bayad[1]	9.08×10^{-3}	2.999	50	FL	35-75
Synodontis schall[1]	8.69×10^{-3}	3.266	50	FL	19-28
Sarotherodon niloticus[3]	2.08×10^{-2}	3.013	66	TL	20-63
Lates niloticus[2]	1.32×10^{-2}	2.99	140	TL	31-175
Lates longispinis[4]	1.01×10^{-2}	2.97	79	TL	16-46

* Lengths were measured to the nearest mm and weights normally to more than 1% accuracy.

[1] From sub-samples of data collected by J. Lock.

[2] From a sub-sample of data collected by A. J. Hopson.

[3] See sections 6.II.6 and 6.II.7.

[4] From a sub-sample of data collected by A. McLeod.

APPENDIX 6.II.2

Hydrocynus forskalii mean weight for each cm length group (corrected for mid-class interval).

TL Group (cm)	Weight (kg)	TL Group (cm)	Weight (kg)	TL Group (cm)	Weight (kg)
20	0.05	44	0.53	68	2.02
21	0.06	45	0.57	69	2.11
22	0.07	46	0.61	70	2.21
23	0.07	47	0.65	71	2.30
24	0.08	48	0.70	72	2.40
25	0.10	49	0.74	73	2.51
26	0.11	50	0.79	74	2.62
27	0.12	51	0.84	75	2.72
28	0.14	52	0.89	76	2.84
29	0.15	53	0.94	77	2.95
30	0.17	54	1.00	78	3.07
31	0.18	55	1.05	79	3.20
32	0.20	56	1.11	80	3.32
33	0.22	57	1.18	81	3.45
34	0.24	58	1.24	82	3.58
35	0.27	59	1.31	83	3.72
36	0.29	60	1.38	84	3.86
37	0.31	61	1.45	85	4.00
38	0.34	62	1.52	86	4.15
39	0.37	63	1.60	87	4.30
40	0.40	64	1.68	88	4.45
41	0.43	65	1.76	89	4.61
42	0.46	66	1.84	90	4.77
43	0.50	67	1.93		

APPENDIX 6.II.3

Citharinus citharus: mean weight for each cm length group (corrected for mid-class interval).

TL Group (cm)	Weight (kg)	TL Group (cm)	Weight (kg)	TL Group (cm)	Weight (kg)
20	0.10	37	0.68	54	2.22
21	0.12	38	0.74	55	2.36
22	0.14	39	0.81	56	2.49
23	0.16	40	0.87	57	2.63
24	0.18	41	0.94	58	2.78
25	0.20	42	1.02	59	2.93
26	0.23	43	1.09	60	3.09
27	0.26	44	1.17	61	3.26
28	0.29	45	1.26	62	3.43
29	0.32	46	1.35	63	3.60
30	0.36	47	1.44	64	3.79
31	0.39	48	1.54	65	3.97
32	0.44	49	1.64	66	4.17
33	0.48	50	1.75	67	4.37
34	0.53	51	1.86	68	4.58
35	0.58	52	1.98	69	4.79
36	0.63	53	2.10	70	5.01

APPENDIX 6.II.4

Distichodus niloticus: mean weight for each cm length group (corrected for mid-class interval).

TL Group (cm)	Weight (kg)	TL Group (cm)	Weight (kg)	TL Group (cm)	Weight (kg)
20	0.06	50	1.34	80	6.93
21	0.07	51	1.44	81	7.24
22	0.08	52	1.54	82	7.56
23	0.09	53	1.65	83	7.88
24	0.11	54	1.76	84	8.22
25	0.12	55	1.87	85	8.56
26	0.14	56	1.99	86	8.92
27	0.16	57	2.12	87	9.29
28	0.18	58	2.25	88	9.66
29	0.20	59	2.39	89	10.06
30	0.23	60	2.54	90	10.46
31	0.26	61	2.69	91	10.87
32	0.29	62	2.84	92	11.29
33	0.32	63	3.01	93	11.73
34	0.35	64	3.18	94	12.17
35	0.39	65	3.35	95	12.64
36	0.43	66	3.54	96	13.11
37	0.47	67	3.73	97	13.59
38	0.52	68	3.93	98	14.09
39	0.57	69	4.13	99	14.60
40	0.62	70	4.34	100	15.11
41	0.67	71	4.56	101	15.65
42	0.73	72	4.79	102	16.21
43	0.79	73	5.03	103	16.77
44	0.86	74	5.28	104	17.37
45	0.93	75	5.53	105	17.95
46	1.00	76	5.79	106	18.54
47	1.08	77	6.06	107	19.17
48	1.16	78	6.34	108	19.80
49	1.25	79	6.63	109	20.45
				110	21.10

APPENDIX 6.II.5

Labeo horie: mean weight for each cm length group (corrected for mid-class interval).

TL Group (cm)	Weight (kg)	TL Group (cm)	Weight (kg)	TL Group (cm)	Weight (kg)
20	0.08	44	0.84	67	3.03
21	0.09	45	0.90	68	3.17
22	0.10	46	0.96	69	3.32
23	0.12	47	1.03	70	3.46
24	0.14	48	1.10	71	3.62
25	0.15	46	1.17	72	3.77
26	0.17	50	1.24	73	3.94
27	0.19	51	1.32	74	4.11
28	0.21	52	1.40	75	4.27
29	0.24	53	1.48	76	4.45
30	0.26	54	1.57	77	4.63
31	0.29	55	1.66	78	4.82
32	0.32	56	1.75	79	5.01
33	0.35	57	1.85	80	5.21
34	0.39	58	1.95	81	5.41
35	0.42	59	2.06	82	5.62
36	0.46	60	2.17	83	5.83
37	0.50	61	2.28	84	6.05
38	0.54	62	2.39	85	6.27
39	0.58	63	2.51	86	6.49
40	0.63	64	2.64	87	6.73
41	0.68	65	2.76	88	6.96
42	0.73	66	2.89	89	7.21
43	0.79			90	7.46

APPENDIX 6.II.6

Barbus bynni: mean weight for each cm length group (corrected for mid-class interval)*.

FL Group (cm)	Weight (kg)	FL Group (cm)	Weight (kg)	FL Group (cm)	Weight (kg)
20	0.10	44	1.49	67	6.25
21	0.12	45	1.61	68	6.58
22	0.14	46	1.73	69	6.91
23	0.17	47	1.87	70	7.27
24	0.19	48	2.00	71	7.62
25	0.22	49	2.15	72	8.00
26	0.25	50	2.30	73	8.39
27	0.28	51	2.46	74	8.79
28	0.32	52	2.63	75	9.19
29	0.36	53	2.81	76	9.63
30	0.41	54	2.99	77	10.07
31	0.45	55	3.19	78	10.52
32	0.51	56	3.39	79	10.99
33	0.56	57	3.60	80	11.47
34	0.62	58	3.82	81	11.97
35	0.68	59	4.05	82	12.49
36	0.75	60	4.29	83	13.01
37	0.83	61	4.54	84	13.56
38	0.91	62	4.80	85	14.12
39	0.99	63	5.07	86	14.69
40	1.08	64	5.35	87	15.29
41	1.17	65	5.64	88	15.89
42	1.27	66	5.94	89	16.52
43	1.38			90	17.16

*Partly from data collected by A.M.S. Mraja

APPENDIX 6.II.7

Sarotherodon niloticus: mean weight for each cm length group (corrected for mid-class interval).*

TL Group (cm)	Weight (kg)	TL Group (cm)	Weight (kg)	TL Group (cm)	Weight (kg)
15	0.08	32	0.75	49	2.65
16	0.10	33	0.82	50	2.81
17	0.11	34	0.89	51	2.98
18	0.14	35	0.97	52	3.16
19	0.16	36	1.06	53	3.35
20	0.19	37	1.15	54	3.54
21	0.22	38	1.24	55	3.74
22	0.25	39	1.34	56	3.94
23	0.28	40	1.45	57	4.16
24	0.32	41	1.56	58	4.38
25	0.36	42	1.67	59	4.61
26	0.40	43	1.79	60	4.85
27	0.45	44	1.92	61	5.09
28	0.50	45	2.05	62	5.22
29	0.56	46	2.19	63	5.61
30	0.62	47	2.34	64	5.88
31	0.68	48	2.49	65	6.16

*Data entirely from a sub-sample collected by J. R. N. Ogari

APPENDIX 6.II.8

The relationship between total length and fork length for various commercial species of fish.

Regression equation: $FL = a + bTL$ (when FL is the dependent variable)

Species	Dependent variable	Intercept (a) in cm	Regression coefficient* (b)	Sample size	Range of independent variable (cm)	Sy.x[1]
Hydrocynus	FL	-0.78	0.850 ± 0.010	54	25 - 68	0.49
"	TL	0.84	1.174 ± 0.014	54	21 - 57	0.57
Citharinus	FL	-2.53	0.92 ± 0.08	10	34 - 60	0.74
"	TL	3.32	1.08 ± 0.09	10	28 - 52	0.80
Distichodus	FL	-1.77	0.919 ± .015	49	38 - 84	0.72
"	TL	2.45	1.076 ± .034	49	33 - 75	0.78
Labeo	FL	-1.30	0.895 ± .021	26	26 - 78	0.61
"	TL	1.59	1.114 ± .026	26	22 - 68	0.68

* Coeff. of Regression ± 95% confidence limits.

[1] sy.x = Standard deviation from regression.

Measurements were made to 0.1 cm accuracy.

APPENDIX 6.II.9

The relationship between length and operculum measurements in various species of commercial fish.

Regression equation: $l = a + br$
where l = total length (TL) or fork length (FL) in cm.
r = operculum measurement r_1 or r_2 in mm (see Fig 6.II.1

Species	Dependent variable	Intercept (a) in cm	Regression coefficient (b)	Sample size	Independent variable	Range of r	$s_{y.x}$
Hydrocynus	TL	5.46	2.11 ± .11	20	r_1*	10 - 30	1.49
"	TL	8.63	1.51 ± .12	20	r_2	14 - 39	2.19
Citharinus	TL	8.57	1.01 ± .12	38	r_1	27 - 53	2.10
"	TL	1.54	1.20 ± .12	37	r_2*	28 - 48	1.88
Distichodus	TL	-1.65	2.18 ± .18	49	r_1	18 - 38	1.93
"	TL	-4.33	1.97 ± .14	49	r_2*	21 - 44	1.73
Labeo	TL	1.62	2.33 ± .21	26	r_1	12 - 35	2.65
"	TL	-2.54	1.97 ± .10	26	r_2*	15 - 41	1.56
Barbus bynni	FL	4.91	1.40 ± .12	35	r_1	19 - 47	2.46
" "	FL	3.44	1.27 ± .09	35	r_2*	21 - 50	1.99
Lates niloticus	TL	5.27	1.20		r_2		

* Variables used preferentially in bone measurements.

APPENDIX 6.III

Mean weights (in kg) of different species sold each month to the cooperative branches.

The values were calculated from operculer bone measurements unless marked by the following superscripts:

[1] calculated from length measurements of dried fish.

[2] calculated (or interpolated) from experimental gillnet and commercial mesh size data.

Mean weights for species in months not measured were estimated by interpolation taking into account current and seasonal trends.

Kalokol includes Namudak and East Shore unless otherwise indicated. Kalokol values were used for fish traded through Eliye.

Numbers in parentheses were the sample sizes. Those marked with asterisk exceeded the monthly totals because they were measured from stocks which included some fish purchased during the previous month.

Hydrocynus forskalii (Means over 1973 and beginning of 1974, no trends apparent).

All other branches	Nachukui	Lowarengak	Todenyang
2.0 (206)	2.3 (37)	2.3 (42)	2.6 (25)

Citharinus citharus

		Kerio	Kalokol	Kataboi	Nachukui	Lowarengak	Todenyang
Oct	72	-	2.62(100)	-	-	-	-
Nov		-	2.34(100)	-	-	-	-
Dec		2.13(102)	2.33(100)	1.74(128)	2.34(48)	2.40(251)	2.45(107)
Jan	73	2.06 (96)	2.28 (99)	2.15 (17)	2.17(97)	2.33 (99)	2.56 (97)
Feb		2.41 (99)	2.75(200)	2.48(200)	2.44(95)	1.48(200)	2.65(100)
Mar		2.45(179)	2.50(199)	4.42 (51)	2.36(22)	2.47(182)	2.41(195)
Apr		2.42(127)	2.15 (54)	-	2.30 (7)	2.26(160)	2.47(199)
May		2.22(161)	1.86 (22)	-	-	2.41 (71)	2.35(186)
Jun		2.16 (25)	2.47 (28)	2.00 (8)	-	2.53 (41)	2.72(199)
Jul		2.53 (39)	2.18 (50)	2.11 (12)	-	2.35(102)	2.61(200)
Aug		2.30(108)	2.39 (99)	2.35 (21)	2.48(13)	2.58(188)	2.58(198)
Sep		2.33 (21)	2.43(100)	2.70 (16)	2.84(37)	2.67(188)	2.73(199)
Oct		2.13 (91)	2.39(201)	2.52 (8)	2.42(27)	2.59(166)	2.61(200)
Nov		2.21(130)	2.32(126)	2.28 (15)	-	2.77 (57)	2.58(191)
Dec		2.14 (85)	2.48 (61)	2.29 (21)	2.35 (6)	2.28 (76)*	2.50(198)
Jan	74	2.16(134)	2.19(131)	2.15 (20)	2.03 (8)	2.17 (84)	2.45(200)
Feb		2.57 (84)	2.20(125)	2.32 (16)	-	2.30 (24)	2.56(148)
Mar		-	-	-	-	-	2.59^1(193)
Apr		-	-	-	-	2.38^1(158)	-
Jun		-	-	-	-	1.68^1 (43)	-
Aug		-	-	-	-	2.23^1(130)	-
Sep		-	-	2.30^1(61)*	-	-	-
Oct		-	-	2.16^1(21)*	-	2.84^1 (54)*	-

contd.

APPENDIX 6.III (contd.)

Mean Weights (contd.)

Distichodus niloticus

	Kerio	Kalokol	Kataboi	Nachukui	Lowarengak	Todenyang
Oct 72	-	4.67(100)	-	-	-	-
Nov	-	4.13(100)	-	-	-	-
Dec	4.72 (98)	4.32(100)	2.99(198)	5.45(172)	5.48(153)	5.55 (61)
Jan 73	4.56 (83)	3.23(100)	3.00 (42)	4.55 (96)	3.20 (94)	5.43 (87)
Feb	4.51 (97)	2.80(200)	1.87(195)	2.73 (94)	9.14(200)	6.98(102)
Mar	4.19(148)	3.05(173)	1.78(181)	2.86 (43)	5.42 (86)	4.87(195)
Apr	4.44 (78)	3.29(129)	1.85(180)	3.24 (38)	2.69(184)	3.45(189)
May	4.76 (40)	3.05 (92)	2.21(154)	2.34 (88)	3.74(174)	4.65(170)
Jun	3.92 (13)	3.50 (67)	2.06(179)	2.20 (92)	2.89(200)	4.83(195)
Jul	3.82 (34)	2.85 (35)	2.01(187)	2.50(193)	3.62(196)	4.72(198)
Aug	4.05 (37)	2.90 (27)	2.05(189)	2.57(177)	4.24(122)	5.46(196)
Sep	4.57(175)	3.49(107)	2.71(195)	3.49(194)	4.75 (51)	5.41 (95)
Oct	4.41(202)	4.26(126)	2.90(188)	3.94(199)	5.34 (78)	5.01(196)
Nov	4.72 (69)	3.91 (66)	2.75(105)	3.96(193)	4.83 (89)	5.30(172)
Dec	4.30 (69)	3.68 (10)	2.97(100)	3.85(151)	4.86 (44)	5.31 (78)
Jan 74	4.08 (45)	3.63 (62)	2.58 (37)	3.11 (16)	4.08 (5)	5.16 (85)
Feb	4.87(137)	3.07 (30)	2.32 (39)	2.84(107)	2.69 (13)	5.35 (56)
Mar	-	2.38^{1}(91)	2.18^{1}(200)*	-	2.61^{1}(121)	-
May	-	-	1.76^{1}(200)	-	2.28^{1}(139)	-
Jun	-	2.01^{1}(50)	-	-	-	-
Jul	-	-	2.65^{1}(164)	-	4.16^{1} (80)	-
Sep	-	2.26^{1}(60)	1.99^{1}(173)	3.38^{1}(154)	3.80^{1}(128)*	-
Oct	-	3.05^{1}(11)	-	-	-	-
Nov	-	-	1.77^{1}(200)	3.05^{1}(135)	4.61^{1}(125)	-

contd./

APPENDIX 6.III (contd.)

Mean Weights (contd.)

Labeo horie

	Kerio	Kalokol	Kataboi	Nachukui	Lowarengak	Todenyang
Oct 72	-	3.20(100)	-	-	-	-
Nov	-	2.92(100)	-	-	-	-
Dec	2.32(100)	3.09 (98)	3.16(268)	3.41(160)	3.20(143)	2.96 (65)
Jan 73	2.37 (71)	2.76(100)	2.89 (99)	3.22 (95)	3.19 (95)	3.10 (77)
Feb	2.50(102)	2.74(200)	2.71(198)	3.21(180)	3.04(197)	3.20 (80)
Mar	2.41(197)	2.82(194)	2.74(186)	2.70(146)	3.11(199)	3.10(147)
Apr	2.32(170)	3.07(186)	2.71(198)	2.84(150)	2.89(199)	2.80(191)
May	2.19(114)	3.20(165)	3.00(182)	3.00(140)	3.20(124)	3.05(131)
Jun	1.99(190)	2.90(197)	2.84(193)	3.05(200)	3.04(200)	3.04(183)
Jul	1.95(200)	2.96(200)	2.78(207)	3.22(188)	3.12(200)	3.18(190)
Aug	2.08(196)	2.95(150)	2.75(198)	3.25(192)	2.91(218)	3.28(183)
Sep	2.14(197)	2.86(125)	2.94(200)	3.22(198)	2.86(158)	3.36(200)
Oct	2.47(198)	3.10(193)	2.98(191)	3.21(199)	2.82 (99)	2.87(194)
Nov	2.42(132)	3.04 (55)	2.96(199)	2.97(334)	2.98 (37)	2.95(193)
Dec	2.19(200)	3.14 (30)	2.65(199)	2.83(205)	2.63 (21)	3.01(199)
Jan 74	2.34(211)	2.73(209)	2.50(192)	2.69(195)	2.58 (77)	2.80(196)
Feb	2.72(188)	2.87(191)	2.61(200)	2.83(201)	2.69(210)	3.20(190)
Mar	1.92[1](200)	2.14[1](200)	-	-	-	-
Apr	-	-	2.12[1](200)	-	2.50[1](200)	-
May	1.52[1](200)	1.71[1](200)	-	-	-	-
Jun	-	-	2.24[1](200)	-	2.15[1](200)	-
Jul	1.61[1](200)	2.15[1](200)	-	-	-	-
Aug	-	-	2.36[1](200)	-	3.07[1](200)	-
Sep	1.80[1](200)	2.37[1](374)	2.43[1](240)	-	-	-
Oct	-	2.27[1](137)	2.46[1](200)	2.53[1](200)	2.91[1](200)	-
Nov	1.85[1](200)	-	-	-	-	-

contd./

APPENDIX 6.III (contd.)

Mean Weights (contd.)

Barbus bynni

	Kerio	Kalokol	Kataboi	Nachukui	Lowarengak	Todenyang
Feb 73	-	-	-	-	-	2.49 (94)
Mar	-	-	-	-	-	2.46 (52)
Jun	-	-	-	1.93 (93)	2.35(201)	2.69(100)
Jul	-	3.58 (5)	-	1.97 (97)	-	-
Aug	-		-	2.07 (93)	1.81(100)	-
Sep	-	4.24 (5)	-	1.75 (90)	1.61(113)	2.62 (24)
Oct	2.17(21)	-	-	1.80(103)	1.61 (95)	2.70 (29)
Nov	2.12 (4)	-	1.47 (53)	1.67 (7)	1.51(245)	1.81(100)
Dec	7.79 (5)	3.77 (8)	1.58 (59)	1.33 (91)	1.35(150)	-
Jan 74	3.31(46)		1.46 (59)	1.44 (98)	1.41(106)	-
Feb	2.12(12)	3.61 (8)	1.53 (56)	1.16 (93)	1.29 (87)	-
Mar	-	-	-	-	1.09[1](200)	1.37[1](193)
Apr	-	-	1.71[1](205)	-	[1]-	-
May	-	-	-	-	1.49[1](169)	-
Jun	-	-	2.07[1](179)	-	-	-
Jul	-	-	-	-	2.37[1](201)	-
Sep	-	2.98[1] (4)	1.35[1] (18)	-	3.15[1](200)	-
Oct	-	1.98[1] (4)	-	2.06[1](200)	-	-
Nov	-	-	-	-	2.68[1](398)	-

Clarias lazera

	Kerio	Kalokol
Apr 74	3.17[1](91)	.80[1](21)
Jun	4.33[1](59)	-
Aug	3.35[1](99)	1.22[1](26)
Oct	3.22[1](60)	4.00[1](11)

Overall means	Kerio	Kalokol	E. Shore	Kataboi	Nachukui	Lowarengak	Todenyang
presumed:-	3.65	2.5	3.0	3.0	3.5	4.0	5.0

contd./

APPENDIX 6.III (contd.)

Mean Weights (contd.)

Bagrus bayad

	Kerio	Kalokol	Kataboi	Nachukui	Lowarengak	Todenyang
May-Dec 73	-	-	-	-	-	1.50^2
Mar 74	1.74^1(100)*	-	1.67^1 (33)	2.32^1(134)	-	-
Apr	-	1.40^1(138)	-	-	1.86^1(121)	-
May	1.30^1(100)	-	1.59^1(200)	-	-	
Jun	-	2.03^1(119)	-	-	3.08^1 (97)	-
Jul	1.40^1(100)	-	2.18^1(167)	-	-	-
Aug	-	1.93^1(196)	-	-	2.60^1(100)	-
Sep	1.66^1(100)	2.35^1(317)	2.36^1(313)	-	-	-
Oct	-	2.39^1(399)	-	-	2.73^1(135)	-
Nov	1.57^1(100)	-	-	2.51^1(118)	-	-

Overall means presumed:-	Kerio	Kalokol (& E. Shore)	Namudak	Kataboi	Nachukui ,Lowarengak&Todenyang
1972 & 1973:	1.5	1.5	1.5	1.5	1.5
1974:	1.5	2.0	2.5	2.0	2.4

(increases in 1974 due to greater number of long-lines catching larger fish, and more fishing in deeper water).

Lates spp.

	Kerio	Kalokol	Kataboi	Nachukui	Lowarengak	Todenyang
Dec 72	5.57(108)	3.01 (41)	-	2.75 (40)	2.46 (35)	2.74 (25)
Jan 73	5.21(105)	2.57 (32)	-	2.84 (86)	2.11 (79)	-
Feb	5.41(100)	1.83 (37)	-	3.19 (64)	2.83 (60)	2.31 (12)
Mar	6.29(100)	2.49 (56)	-	3.45 (33)	3.40 (41)	3.84 (52)
Apr	5.56 (96)	2.97 (32)	-	3.26 (99)	3.07 (15)	2.45 (24)
May	6.63 (99)	2.81 (38)	-	3.82(131)	3.04 (93)	2.25 (16)
Jun	5.63(101)	2.95 (39)	2.15 (5)	4.61(100)	2.99(100)	3.41 (58)
Jul	5.08(100)	2.43 (23)	1.77 (26)	3.27(190)	3.67(100)	2.59 (46)
Aug	5.54 (99)	2.69 (60)	1.80 (24)	2.10(176)	2.83(165)	2.77 (11)
Sep	6.22(100)	2.55 (41)	1.95 (37)	2.97(158)	1.77 (57)	2.52 (27)
Oct	5.56(102)	4.53 (32)	1.80 (24)	4.75 (87)	2.23 (28)	2.64 (15)
Nov	5.87 (99)	3.31 (21)	1.65 (29)	2.90 (92)	1.97 (17)	2.35 (29)
Dec	5.84(100)	4.26 (11)	2.34 (41)	3.24 (87)	3.85 (4)	2.40 (11)
Jan 74	5.91(112)	4.86 (33)	2.33 (28)	4.11 (79)	-	2.46 (24)
Feb	5.89(141)	3.24 (61)	2.79 (17)	6.17 (36)	-	2.01 (11)
Mar	-	-	1.92^1(83)	-	4.29^1(143)	-
Apr	4.84^1(201)	2.86^1(99)	2.01^1(105)	-		
May	-	-	1.92^1(100)	-	2.99^1(163)	4.15^1(99)
Jun	5.66^1(200)	-	1.82^1 (96)	-	-	-
Jul	-	2.49^1(90)	3.55^1 (85)	-	4.77^1(100)	-
Aug	5.67^1(200)	-	5.92^1 (82)	-	-	-
Sep	-	3.75^1(207)	2.68^1 (80)	4.49^1(101)	4.53^1(100)	-
Oct	4.26^1(200)	3.50^1 (59)	2.44^1(148)	-	-	-
Nov	-	-	2.27^1 (99)	-	5.07^1(200)	-

Note: For reasons already stated all the above results for Lates were underestimated with the exception of data for Kerio. The latter agree closely with experimental gillnet data. By analysing 1973 gillnet data estimated mean weights of 5.0kg for Kalakol (only), 6.0kg for Kalakol (East Shore) and 5.5kg for Todenyang were obtained. Values for other regions were assumed to be as follows:- Namudak, 4.0kg; Kataboi, 3.5kg; Nachukui, 4.3kg; Lowarengak, 4.5kg.

APPENDIX 6.III

Mean Weights (contd.)

Sarotherodon spp

	Kerio	Kalokol
Mar 74	1.48(100)	1.67 (89)
Apr	1.41(100)	-
May	1.52(100)	1.32 (66)
Jun	1.39(100)	-
Jul	1.67(100)	1.56 (35)
Aug	1.37(100)	-
Sep	1.44(100)	1.52 (4)
Oct	1.52(100)	-
Nov	1.54(100)	-

Value of 1.5 Kg was assumed for other regions.

Species of lesser importance were estimated from dried weights of very small samples at the cooperatives. Values used are listed below.

Heterotis niloticus: Kerio: 2.5 Kg, Other regions:- 3.0 Kg.

Mormyridae spp.: all regions: 1.0 Kg.

Gymnarchus niloticus: all regions: 3.0 Kg.

Alestes spp.: all regions: 1.0 Kg.

Heterobranchus sp. all regions: 6.0 Kg.

Bagrus docmac: Todenyang: 3.0 Kg, other regions 2.5 Kg.

APPENDIX 6.IV

Analytical methods used in the estimation of fishing effort

6.IV.1 Relationship between V and F.

These factors are defined on page 365. V is not expected to be directly proportional to F, since when the fishing improves, although more fishermen are active, the number of visits per fisherman per week is proportionately greater. This is borne out by the analyses, which all show that the relationship was most accurately described as a power curve $F = a_o V^{a1}$ with $a_1 < 1$. This is derived from the least squares, linear regression of Log V on Log F. The table below summarizes the results.

APPENDIX 6.IV.1 Relationship between V and F (see text) as $F = a_o V^{a1}$.

Region	a_o	$a_1 \pm 95\%$ conf. limits	r (coeff. of correlation)
Todenyang	10.29	0.570 ± .089	.965
Lowarengak	8.72	0.507 ± .101	.952
Kerio	8.39	0.513 ± .094	.956
Namudak	1.93	0.79 ± .21	.909
Kalokol only	1.45	0.858 ± .081	.987
East Coast	1.20	0.878 ± .103	.980
Lowarengak & Kerio combined	8.34	0.514 ± .037	.983

As would be expected, the relationships as shown in the table are not identical. The average travelling distance of fishermen travelling from their homes to the cooperative 'buying point' varies from region to region. The ranges of V and F vary likewise. Such variations probably account for the differences between the relationships. There are, however, similarities between the first three cooperatives listed in the table and Lowarengak and Kerio are not significantly different, as would be expected from their mean travelling distance and range of values. Due to lack of time Kataboi and Nachukui recordings were not analysed in respect to F, but V was available, and since the factors mentioned above are similar in all these areas the combined Lowarengak-Kerio formula was used. Table 6.22 includes these computed values.

6.IV.2 Method to predict the commercial fishing effort (F) outside the calibration period November 1973 - February 1974

Most recorders were trained to record fish in 'lots' or 'batches' under species as the catch from each fisherman was weighed. An example of part of a data sheet is shown in Figure 6.IV.1.

The ringed numbers indicate the number of fish of that species brought in by an individual fisherman and each constitutes a batch for that species. Sometimes when fish were filleted, they were split into more than one fillet per fish and the recorder estimated the number of fish as shown for *Lates* (Figure 6.IV.1). These also constitute batches.

Thus, in the example shown in Fig. 6.IV.1, 47 Distichodus were sold in 17 batches. There is some relationship between the number of batches and the number of visits of fishermen, V, which is in turn related to F as shown in Appendix 6.IV.1. In fact, the number of batches of major species summed over the week, defined as 'b', all showed significant positive correlations with V, the number of visits of fishermen. The correlations would be closer if one species of fish was either present in all the fishermen's catches or in a fixed proportion of them. This was not usually the case, and two to four species (most often three) contributed relatively large numbers of batches (b) in varying proportions. A much closer correlation was obtained if the number of batches of the three species contributing the most batches each week, were added to give a total (B). The relationship between total batches (B) and F was satisfactorily expressed by a power curve relationship:-

$$F = a_o B^{a_1} \qquad (i)$$

It was realized that the deviations from these regressions could be largely due to variations in the relative number of batches of the three major species. If batch numbers were similar for each of the major species one would expect a relatively large number of fishermen to contribute two or three batches at a visit and the formula would overestimate F. Conversely, if the batches were composed chiefly of one species, F would be underestimated.

In an attempt to allow for this, a 'factor of homogeneity' or 'H' was devised and tested. It is defined as follows:

$$H = \frac{1}{2B}\left(\frac{n}{n-1}\right)\sum_{1}^{n}\left|\frac{B}{n} - b_i\right|$$

Where b_i = number of batches of the i^{th} species

n = number of species (= 3),

$B = \sum_1^n b_i$ = total batch number.

The equation is less complex than appears at first sight. The positive deviations of each batch number (b_i) from the mean (B/n) are summed, divided by B to make it independent of the total batch number, and multiplied by $\frac{1}{2}(\frac{n}{n-1})$ to make $0 \leq H \leq 1$. It can be seen that when all b_i's are equal, H = 0 and when all b_i's except one are 0, H = 1 meaning maximum homogeneity.

Tests were carried out to determine whether the use of factor H would result in a significant improvement in the accuracy of predicting F. Analyses of three-variable regressions indicate that in all cases the new independent variable 'H' improved the correlation, and in only two cases (Todenyang and Kalokol only) was the coefficient of H not significantly more than zero at the 5% level. The formula is as follows:

$$F = a_o B^{a_1} a_2^{H} \qquad (ii)$$

Which when transformed by natural logarithms produced the equation of a plane:

$$\log_e F = \log_e a + a_1 \log_e B + H \log_e a_2 \qquad \text{(iii)}$$

from which the regression was calculated in the normal way with $\log_e B$ and H as the independent variables and $\log_e F$ as the dependent variable.

Comparing equation (i) with (ii) reveals the effect of the component a_2 which should increase as H increases. This happens when $a_2 > 1$ and in all the regressions this condition was satisfied.

The following table summarises the results of the regressions for data obtained during the 15 week calibration period between November 1973 and February 1974 using equations (ii) and (iii) above. In the last three regressions in Appendix 6.IV.2 data from regions with similar equations have been combined. Where values of B or H lay outside the calibration range, estimates of F were made by using the combined regression value from the last three lines of Appendix 6.IV.2 which included the region concerned. It should be noted that the last column shows the maximum error (as a % of the F value calculated) of a single prediction of F with 95% confidence. When mean values of F, or mean values of catch per effort calculated from F are quoted, the % errors will be much less than these. The analyses involved weeks when the Cooperative branches were open between 3 and 6 days inclusive per week. A separate analysis showed that within these limits, variation in the number of days open per week had no significant effect on the calibration.

This method for estimating F was not visualised at the start of the present investigations and two recorders were allowed to use their preferred methods of tabulating data. As a consequence, records of batch number are not available for the following cooperatives during the periods indicated:

Todenyang:	15th May 1972 to 8th January 1973
Nachukui:	17th July 1972 to 24th September 1973

Estimates of F made for these two periods are more approximate and are based on significant correlations ($P = < 0.001$) from subsequent observations. The 95% confidence limits for single predictions are 35% to 45%.

Weekly values of F estimated for the whole study period, using the method described in this appendix, have been combined and the annual means for each cooperative presented in Table 6.25.

APPENDIX 6.IV.2

Regression Values from equations (ii), (iii)

Region	r	a_o	$a_1 \pm$ 95% conf. limit	$\log_e$ $\pm$95% conf. limit	a_2	Max. % error in prediction of single 'F' with 95% confidence
Todenyang (1)	0.964	10.22	0.530 ± .093	0.080 ± .442	1.08	15%
Lowarengak (2)	0.943	9.73	0.443 ± .104	0.297 ± .209	1.35	16%
Nachakui (3)	0.992	9.20	0.432 ± .041	0.311 ± .260	1.37	7%
Kataboi (4)	0.935	7.69	0.458 ± .150	0.383 ± .220	1.47	16%
Kerio (5)	0.947	10.38	0.417 ± .149	0.463 ± .333	1.59	15%
Namudak (6)	0.944	2.72	0.618 ± .161	1.08 ± .86	1.94	18%
Kalokol only (7)	0.976	0.602	0.964 ± .151	0.54 ± 1.32	1.71	25%
East Coast (through Kalokol)	0.990	0.461	0.960 ± .096	0.549 ± .729	1.73	20%
(2),(3)&(4):	0.986	6.731	0.481 ± .038	0.447 ± .082	1.56	11%
(2)&(5):	0.966	8.786	0.452 ± .066	0.357 ± .119	1.43	13%
(2),(5),(6)&(7):	0.975	2.520	0.668 ± .065	0.221 ± .194	1.25	24%

APPENDIX 6.V.1

Gillnet selectivity in Hydrocynus forskalii length frequencies of fish caught in experimental nets of various mesh sizes.

	Stretched mesh sizes in inches						
TL group (cm)	2	3	4	5	6	7	8
20	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-
22	1	-	-	-	-	-	-
23	-	-	-	-	-	-	-
24	1	-	-	-	-	-	-
25	1	-	-	-	-	-	-
26	18	1	1	-	-	-	-
27	32	-	-	-	-	-	-
28	68	-	-	1	-	-	-
29	63	-	-	-	-	-	-
30	71	-	-	1	-	-	-
31	44	-	1	1	-	-	-
32	38	-	1	-	-	-	-
33	29	-	-	-	-	-	-
34	16	3	1	-	-	-	-
35	18	-	-	-	-	-	-
36	16	3	-	-	-	-	-
37	8	2	1	1	-	-	-
38	8	7	-	2	-	-	-
39	5	12	-	-	-	-	-
40	-	43	1	-	-	-	-
41	1	53	-	-	-	-	-
42	1	74	-	-	-	-	-
43	1	58	-	-	-	-	-
44	1	71	-	-	-	-	-
45	-	49	1	-	-	-	-
46	1	37	-	-	-	-	-
47	3	20	-	-	-	-	-
48	1	15	-	-	-	-	-
49	-	9	-	-	-	-	-
50	-	-	-	1	-	-	1
51	-	3	3	-	-	-	1
52	-	-	4	-	1	-	-
53	-	-	-	-	-	-	-
54	-	-	1	-	-	-	-
55	-	-	3	1	-	-	-
56	-	-	-	-	-	-	-
57	-	2	1	-	-	-	-
58	-	-	1	2	-	-	-
59	-	-	5	-	-	-	-
60	-	-	9	1	-	-	1
61	-	-	1	1	-	-	-
62	-	-	1	4	-	-	-
63	-	-	2	1	1	-	-
64	-	-	2	2	-	1	-
65	-	1	-	1	1	1	-
66	-	-	-	6	1	1	1
67	-	-	3	4	1	-	-
68	-	-	-	7	2	1	1
69	-	-	-	4	4	-	-
70	-	-	-	4	5	-	-

contd./

APPENDIX 6.V.1 (contd.) Sheet 2

	Stretched mesh sizes in inches						
TL group (cm)	2	3	4	5	6	7	8
71	-	-	-	5	1	1	-
72	-	-	-	3	-	-	-
73	-	-	1	3	-	1	-
74	-	-	-	-	-	2	-
75	-	-	-	4	-	-	2
76	-	-	1	1	2	2	-
77	-	-	1	1	1	-	-
78	-	-	-	1	2	1	-
79	-	-	-	1	2	1	-
80	-	-	-	-	-	2	-

APPENDIX 6.V.2

Gillnet selectivity in *Citharinus citharus*: length frequencies of fish caught in experimental nets of various mesh sizes.

	Stretched mesh size in inches				
TL group (cm)	5	6	7	8	9
31	-	-	-	-	-
32	1	-	-	-	-
33	1	-	-	-	-
34	-	-	-	-	-
35	1	1	-	-	-
36	-	1	-	-	-
37	-	-	-	-	-
38	-	-	-	-	-
39	-	1	-	-	-
40	-	-	-	-	-
41	-	-	-	-	-
42	-	-	1	-	-
43	1	-	-	-	-
44	-	-	-	-	-
45	-	-	-	2	-
46	-	-	1	-	-
47	-	-	-	-	-
48	-	-	-	3	-
49	-	-	-	1	-
50	2	-	1	1	1
51	-	1	-	4	-
52	1	-	3	5	-
53	2	-	2	6	-
54	-	-	3	5	-
55	1	4	5	12	-
56	1	2	4	14	-
57	1	4	5	12	-
58	1	3	7	11	3
59	-	1	3	8	-
60	1	-	6	6	-
61	-	-	1	2	1
62	-	-	4	1	-
63	-	1	2	2	-
64	-	-	-	-	-
65	-	-	-	-	-
66	-	-	-	1	-
67	-	-	-	-	-
68	-	-	-	-	-
69	-	-	-	-	-
70	-	-	-	-	-

APPENDIX 6.V.3

Gillnet selectivity in *Distichodus niloticus*: length frequencies of fish caught in experimental nets of various mesh sizes.

	Stretched mesh size in inches						
TL group (cm)	3	4	5	6	7	8	9
23	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-
28	-	-	-	-	-	-	-
29	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-
31	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-
33	-	-	-	-	-	-	-
34	1	-	-	-	-	-	-
35	-	-	-	-	-	-	-
36	-	-	-	-	-	-	-
37	1	-	-	-	-	-	-
38	2	1	-	-	-	-	-
39	1	-	-	-	-	-	-
40	-	1	-	-	-	-	-
41	-	2	-	-	-	-	-
42	1	1	-	-	-	-	-
43	-	4	-	-	-	-	-
44	1	3	-	-	-	-	-
45	-	-	1	-	-	-	-
46	-	1	1	-	-	-	-
47	1	-	-	-	-	-	-
48	-	2	2	1	-	-	-
49	-	-	-	2	-	-	-
50	-	-	-	-	-	-	-
51	-	-	-	-	-	-	-
52	-	1	1	-	-	-	-
53	-	-	-	-	-	-	-
54	-	-	1	-	1	-	2
55	-	-	-	1	-	-	-
56	-	-	1	1	-	-	-
57	-	-	-	-	-	-	-
58	-	-	-	-	1	-	-
59	-	-	-	-	-	-	-
60	-	1	-	-	1	-	1
61	-	-	-	-	1	-	-
62	-	-	-	-	-	1	-
63	-	-	1	-	-	1	-
64	-	-	-	1	-	-	-
65	-	-	-	-	1	1	-
66	-	-	-	-	2	1	-
67	-	-	-	-	1	2	-
68	-	-	-	-	-	-	-
69	-	-	-	-	-	-	-
70	-	-	1	-	1	-	-

contd./

APPENDIX 6.V.3 (contd.) Sheet 2

	Stretched mesh size in inches						
TL group (cm)	3	4	5	6	7	8	9
71	-	-	-	1	1	-	-
72	-	-	-	1	-	1	1
73	-	-	-	-	-	2	-
74	-	-	-	-	-	-	-
75	-	-	-	1	-	2	-
76	-	-	-	-	2	1	1
77	-	-	-	-	-	-	-
78	-	-	-	-	-	-	-
79	-	-	-	-	-	-	-
80	-	-	-	-	-	1	-
81	-	-	-	-	-	-	1
82	-	-	-	1	-	-	-
83	-	-	-	-	-	1	-

APPENDIX 6.V.4

Gillnet selectivity in *Labeo horie*: length frequencies of fish caught in experimental nets of various mesh sizes.

	Stretched mesh size in inches						
TL group (cm)	2	3	4	5	6	7	8
17	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-
19	1	-	-	-	-	-	-
20	-	-	-	-	-	-	-
21	5	-	-	-	-	-	-
22	5	-	-	-	-	-	-
23	15	-	-	-	-	-	-
24	12	1	-	-	-	-	-
25	15	1	-	-	-	-	-
26	9	-	-	-	-	-	-
27	10	1	-	-	-	-	-
28	6	-	-	-	-	-	-
29	5	-	-	-	-	-	-
30	3	2	-	-	-	-	-
31	1	5	-	-	-	-	-
32	1	9	-	-	-	-	-
33	-	18	-	-	-	-	-
34	1	18	-	-	-	-	-
35	1	47	-	-	-	-	-
36	3	36	1	-	-	-	-
37	1	42	-	-	-	-	-
38	1	23	-	-	-	-	-
39	2	26	-	-	-	-	-
40	-	15	1	-	-	-	-
41	-	13	2	-	-	-	-
42	-	8	2	-	-	-	-
43	-	9	1	-	-	-	-
44	-	8	3	1	-	-	-
45	-	3	8	1	-	-	-
46	-	2	3	-	-	-	-
47	-	-	11	1	-	-	-
48	-	1	16	3	-	-	-
49	-	1	7	2	-	-	-
50	-	-	10	2	-	-	-
51	-	1	11	5	-	-	-
52	-	-	6	7	1	-	-
53	-	-	5	9	-	-	-
54	-	-	12	13	-	-	-
55	-	-	5	28	-	1	-
56	-	-	5	21	-	-	-
57	-	-	2	22	1	-	-
58	-	-	3	16	1	1	-
59	-	-	3	15	2	-	-
60	-	-	1	12	1	-	1
61	-	-	-	17	4	-	-
62	-	-	-	9	5	-	-
63	-	-	-	10	3	-	-
64	-	-	-	6	5	-	-
65	-	-	-	9	3	-	-

contd./

APPENDIX 6.V.4 (contd.) Sheet 2

TL group (cm)	Stretched mesh size in inches						
	2	3	4	5	6	7	8
66	-	-	-	4	5	-	-
67	-	-	-	8	8	-	-
68	-	-	-	3	8	2	-
69	-	-	-	4	7	3	2
70	-	-	-	3	3	1	-
71	-	-	-	1	1	2	-
72	-	-	-	2	1	1	-
73	-	-	-	1	1	1	-
74	-	-	-	-	1	1	-
75	-	-	-	-	-	2	-
76	-	-	-	-	-	-	1
77	-	-	-	-	-	1	-
78	-	-	-	1	-	-	1

APPENDIX 6.V.5

Gillnet selectivity in Barbus bynni: length frequencies of fish caught in experimental nets of various mesh sizes.

	Stretched mesh size in inches								
FL group (cm)	2	3	4	5	6	7	8	9	10
14	-	-	-	-	-	-	-	-	-
15	1	-	-	-	-	-	-	-	-
16	6	-	-	-	-	-	-	-	-
17	7	-	-	-	-	-	-	-	-
18	7	-	-	-	-	-	-	-	-
19	15	-	1	-	-	-	-	-	-
20	26	2	-	-	-	-	-	-	-
21	18	2	-	-	-	-	-	-	-
22	18	22	-	-	-	-	-	-	-
23	9	24	-	-	-	-	-	-	-
24	4	34	-	-	-	-	-	-	-
25	2	38	1	-	-	-	-	-	-
26	2	32	-	-	-	-	-	-	-
27	1	46	-	-	-	-	-	-	-
28	2	42	-	-	-	-	-	-	-
29	1	33	8	-	-	-	-	-	-
30	1	21	15	2	-	-	-	-	-
31	2	31	25	2	-	-	-	-	-
32	1	20	36	1	-	-	-	-	-
33	1	11	28	1	-	1	-	-	-
34	-	10	21	1	-	-	-	-	-
35	-	5	24	1	1	-	-	-	-
36	-	6	18	6	1	-	-	-	-
37	-	2	25	5	1	-	-	-	-
38	-	4	21	19	3	1	-	-	-
39	-	3	15	14	1	2	1	-	-
40	-	1	10	14	1	-	-	-	-
41	-	-	8	8	4	-	-	-	-
42	-	-	6	10	2	-	-	-	-
43	-	-	10	7	4	1	-	-	-
44	-	-	6	8	2	-	2	-	-
45	-	-	4	6	7	1	-	-	-
46	-	-	2	4	5	1	1	-	-
47	-	-	1	6	3	3	-	-	-
48	-	-	-	3	8	4	-	-	-
49	-	-	-	3	4	2	-	-	-
50	-	-	1	2	4	6	1	-	-
51	-	-	1	1	1	7	1	-	-
52	-	-	-	3	4	5	-	-	-
53	-	-	-	3	3	5	3	-	-
54	-	-	-	-	-	5	1	-	-
55	-	-	-	3	-	5	5	-	-
56	-	-	-	-	1	4	4	-	1
57	-	-	-	-	3	6	7	-	-
58	-	-	-	-	1	1	1	2	-
59	-	-	-	1	-	2	2	1	-
60	-	-	-	1	1	1	2	-	-

contd./

APPENDIX 6.V.5 (contd.) Sheet 2

FL group (cm)	Stretched mesh size in inches								
	2	3	4	5	6	7	8	9	10
61	-	-	-	-	-	2	2	2	-
62	-	-	-	-	-	-	1	-	-
63	-	-	-	-	1	-	2	-	-
64	-	-	-	-	-	2	-	-	-
65	-	-	-	-	-	-	-	-	-
66	-	-	-	-	-	-	1	-	-
67	-	-	-	-	-	3	-	-	-
68	-	-	-	-	-	1	-	-	-
69	-	-	-	-	-	1	-	-	-
70	-	-	-	-	-	1	-	-	-
71	-	-	-	-	-	-	-	-	-
72	-	-	-	-	-	1	-	-	-
73	-	-	-	-	-	-	-	-	-

APPENDIX 6.V.6

Gillnet selectivity in Bagrus bayad: length frequencies of fish caught in experimental nets of various mesh sizes.

FL group (cm)	Stretched mesh size in inches								
	2	3	4	5	6	7	8	9	10
15	-	-	-	2	-	-	-	-	-
16	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-
20	1	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	-	-
22	2	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-
24	1	-	-	-	-	-	-	-	-
25	1	-	-	-	-	-	-	-	-
26	2	-	-	-	-	-	-	-	-
27	-	-	-	1	-	-	-	-	-
28	1	-	1	-	-	-	-	-	-
29	-	-	-	-	-	-	-	-	-
30	1	1	-	1	-	-	-	-	-
31	-	1	-	-	-	-	-	-	-
32	-	1	-	1	-	1	1	-	-
33	-	1	2	1	1	-	1	1	-
34	-	1	-	-	-	-	-	-	-
35	-	2	-	1	-	-	2	-	-
36	-	1	-	1	-	-	2	-	-
37	-	3	-	1	-	1	2	-	-
38	-	-	-	-	-	1	1	-	-
39	-	1	-	-	1	-	-	-	-
40	-	3	3	2	-	-	2	-	-
41	-	-	-	1	-	-	2	-	-
42	-	2	1	2	-	-	-	-	-
43	-	-	1	1	1	1	-	-	-
44	-	2	-	1	-	-	-	-	-
45	-	2	6	2	-	-	-	-	-
46	-	2	2	1	-	-	-	-	-
47	-	-	3	2	-	-	-	-	-
48	-	-	6	1	-	-	2	-	-
49	-	-	3	3	-	-	-	-	-
50	-	-	4	2	-	-	-	-	-
51	-	-	6	4	-	-	-	-	-
52	-	-	3	1	-	-	-	-	-
53	-	-	-	-	-	-	-	-	-
54	-	-	-	1	-	1	-	-	-
55	-	-	-	2	-	-	1	-	-
56	-	-	-	-	-	-	-	-	-
57	-	-	3	3	-	-	-	-	-
58	-	-	2	1	2	1	-	-	-
59	-	-	1	-	1	1	1	-	-
60	-	-	1	-	1	-	-	-	-

contd./

APPENDIX 6.V.6 (contd.) Sheet 2

FL group (cm)	Stretched mesh size in inches								
	2	3	4	5	6	7	8	9	10
61	-	-	3	-	2	-	-	-	-
62	-	-	1	-	1	1	-	-	-
63	-	-	-	-	-	-	-	-	-
64	-	-	1	-	5	-	-	-	-
65	-	-	2	-	-	1	-	-	-
66	-	-	-	1	-	-	1	-	2
67	-	-	-	1	2	2	1	-	-
68	-	1	-	1	1	1	-	-	-
69	-	-	-	-	-	2	2	-	-
70	-	-	1	-	-	1	2	-	-
71	-	-	1	-	-	-	-	-	-
72	-	-	-	-	1	-	1	-	-
73	-	-	1	-	1	-	-	-	-
74	-	-	-	-	-	1	-	-	-
75	-	-	-	-	-	1	-	-	-
76	-	-	1	1	1	1	-	-	-
77	-	-	-	-	-	-	-	-	-
78	-	-	1	-	-	-	-	-	-
79	-	-	1	-	-	-	1	-	-
80	-	-	-	-	1	-	-	-	-
81	-	-	-	-	-	1	-	-	-
82	-	-	-	-	-	1	-	-	-

APPENDIX 6.V.7

Gillnet selectivity in *Synodontis schall*: length frequencies of fish caught in experimental gill nets of various mesh sizes.

	Stretched mesh size in inches								
FL group (cm)	2	3	4	5	6	7	8	9	10
7	-	-	-	-	-	-	-	-	-
8	1	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-
11	1	-	-	1	-	-	-	-	-
12	3	1	-	-	1	-	-	-	-
13	1	-	-	-	1	-	-	-	-
14	14	-	-	1	-	-	-	-	-
15	9	-	-	1	-	-	-	-	-
16	8	2	1	4	-	-	-	-	-
17	20	4	-	4	-	-	-	-	-
18	30	17	1	13	3	1	-	-	-
19	49	59	4	22	2	1	1	-	1
20	53	111	9	40	-	3	-	1	-
21	54	139	13	40	2	2	1	-	-
22	64	128	21	72	2	3	1	-	1
23	62	129	21	61	4	1	3	-	-
24	47	131	49	89	6	3	1	1	-
25	40	111	80	73	7	2	3	1	-
26	19	118	126	44	7	5	4	1	-
27	15	80	113	51	6	4	1	-	-
28	10	42	91	48	5	2	4	-	-
29	3	29	55	22	2	2	-	-	-
30	3	12	34	27	-	1	-	-	-
31	3	3	13	9	2	-	1	-	-
32	-	-	10	8	1	1	-	-	-
33	-	1	4	6	-	1	-	-	-
34	-	-	1	1	-	-	-	-	-
35	-	-	-	-	-	-	-	-	-
36	-	-	-	1	-	-	-	-	-
37	-	-	1	1	-	-	-	-	-
38	-	-	-	-	-	-	-	-	-
39	-	-	-	-	-	-	-	-	-

APPENDIX 6.V.8

Gillnet selectivity in *Schilbe uranoscopus*: length frequencies of fish caught in experimental gillnets of various mesh sizes.

	Stretched mesh size in inches					
FL group (cm)	2	3	4	5	6	7
15	-	-	-	-	-	-
16	1	-	-	-	-	-
17	1	-	-	-	-	-
18	2	-	-	-	-	-
19	5	-	-	-	-	-
20	18	-	-	-	-	-
21	19	2	-	-	1	-
22	22	-	1	-	-	-
23	17	1	-	-	1	-
24	15	3	-	-	-	-
25	25	-	2	-	-	1
26	41	3	-	-	-	-
27	38	10	1	1	-	-
28	31	34	2	-	1	-
29	20	73	2	-	3	-
30	10	78	1	-	-	-
31	4	50	-	-	-	-
32	1	17	1	-	-	-
33	-	4	-	-	-	-
34	-	-	-	-	-	-
35	-	1	-	-	-	-
36	-	-	-	-	-	-
37	-	1	-	-	-	-
38	-	-	-	-	-	-
39	-	1	-	-	-	-

APPENDIX 6.V.9

Gillnet selectivity in *Lates niloticus*: Length frequencies of fish caught in experimental gillnets of various mesh sizes.

	Stretched mesh size in inches							
TL (2cm groups)	3	4	5	6	7	8	9	10
22	-	-	1	1	-	-	-	-
24	-	-	-	-	-	-	-	-
26	-	-	-	-	-	1	-	-
28	-	-	-	-	-	2	-	-
30	2	-	-	-	-	-	-	-
32	-	-	1	1	-	-	-	-
34	-	-	-	-	-	1	-	-
36	-	1	-	-	-	-	-	-
38	-	2	-	-	-	2	-	-
40	1	1	1	1	-	-	-	-
42	-	-	4	2	-	-	-	-
44	1	2	6	1	1	3	1	-
46	-	1	7	5	2	2	-	-
48	-	1	6	1	-	5	-	-
50	-	-	4	1	-	-	-	-
52	-	-	3	4	2	-	-	-
54	-	-	3	3	3	-	-	-
56	-	-	2	5	2	-	-	-
58	-	-	-	2	-	1	1	-
60	-	-	2	4	2	-	-	-
62	-	-	-	5	-	2	-	1
64	-	-	-	3	4	-	-	-
66	-	-	2	2	3	-	-	-
68	-	-	1	1	13	2	-	-
70	-	-	-	4	10	6	2	-
72	-	-	-	1	3	12	-	-
74	-	-	1	1	10	14	2	-
76	-	-	1	1	5	18	3	-
78	-	-	1	1	7	21	1	-
80	-	-	-	-	5	25	5	-
82	-	1	-	-	4	18	5	-
84	-	-	1	-	4	19	4	1
86	-	-	-	-	2	12	7	-
88	-	-	-	-	2	8	4	-
90	-	1	-	-	1	3	3	-
92	1	-	-	-	2	3	6	2
94	-	-	-	-	1	5	2	2
96	-	-	-	-	1	5	1	1
98	-	-	-	-	-	1	-	-
100	-	-	-	-	-	-	2	-
102	-	1	-	-	-	1	1	-
104	-	-	-	-	-	2	-	-
106	-	-	-	-	-	-	-	-
108	-	-	-	-	-	2	-	1
110	-	-	-	-	-	1	-	-
112	-	-	-	-	-	-	-	-
114	-	1	-	-	1	-	-	-
116	-	-	-	-	-	1	-	-
118	-	-	-	-	-	-	-	-
120	-	-	-	-	-	-	-	-

contd./

APPENDIX 6.V.9 (contd.) Sheet 2

	Stretched mesh size in inches							
TL (2cm groups)	3	4	5	6	7	8	9	10
122	-	-	-	-	-	-	-	-
124	-	-	-	-	-	-	-	-
126	-	-	-	-	-	-	-	-
128	-	-	-	-	-	-	-	-
130	-	-	-	-	-	-	-	-
132	-	-	-	-	-	-	-	-
134	-	-	-	-	-	-	-	-
136	-	-	-	-	-	-	-	-
138	-	-	-	-	-	-	-	-
140	-	-	-	-	-	-	-	-
142	-	-	-	-	-	-	-	-
144	-	-	-	-	-	-	-	-
146	-	-	-	-	-	-	-	-
148	-	-	-	-	-	-	-	-
150	-	-	-	-	-	-	-	-
152	-	-	-	-	-	-	-	-
154	-	-	-	-	-	-	-	-
156	-	-	-	-	-	-	-	-
158	-	-	-	-	-	-	-	-
160	-	-	-	-	-	-	1	-
162	-	-	-	-	-	-	-	-
164	-	-	-	-	-	1	-	-
166	-	-	-	-	-	-	-	-
168	-	-	-	-	-	-	-	-
170	-	-	-	-	-	-	-	-
172	-	-	-	-	-	-	-	-
174	-	-	-	-	-	-	-	-
176	-	-	-	-	-	-	-	-
178	-	-	-	-	-	-	-	-
180	-	-	-	-	-	-	-	-
182	-	-	-	-	-	1	-	-
184	-	-	-	-	-	1	-	-

APPENDIX 6.V.10

Gillnet selectivity in *Lates longispinis*: Length frequencies of fish caught in experimental gillnets of various mesh sizes.

	Stretched mesh size in inches							
TL group (cm)	2	3	4	5	6	7	8	9
12	-	-	-	-	-	-	-	-
13	1	-	-	-	-	-	-	-
14	-	-	1	-	-	-	-	-
15	-	-	1	-	-	-	-	-
16	2	-	-	-	-	-	-	-
17	6	1	1	-	-	-	-	-
18	11	1	2	-	-	2	-	-
19	54	1	2	-	2	1	-	-
20	60	1	-	-	1	-	-	-
21	59	1	-	-	-	-	-	-
22	48	1	1	-	1	-	-	-
23	33	1	1	-	-	-	-	-
24	31	2	-	-	1	-	-	-
25	25	8	1	-	-	-	-	-
26	18	10	1	-	-	-	-	-
27	15	13	2	1	-	1	1	-
28	10	23	1	-	-	-	-	-
29	16	28	-	2	-	-	-	-
30	12	30	3	-	-	-	-	-
31	9	29	-	4	-	-	1	-
32	5	20	5	-	1	-	-	-
33	9	20	3	1	-	-	-	-
34	8	22	3	-	-	-	-	-
35	4	8	2	-	-	1	-	1
36	4	7	6	-	-	-	-	-
37	3	6	6	-	1	-	-	-
38	2	3	13	1	-	-	-	-
39	1	1	12	-	1	-	-	-
40	-	3	9	1	-	-	-	-
41	-	1	4	-	-	-	-	-
42	-	4	-	1	-	-	-	-
43	-	2	2	1	-	-	-	-
44	-	-	3	-	-	-	-	-
45	-	1	4	1	-	-	-	-
46	-	-	1	1	-	-	-	-
47	-	-	1	1	-	-	-	-
48	-	-	-	-	-	1	-	-
49	-	-	-	1	-	-	-	-
50	-	-	-	2	-	-	-	-
51	-	-	-	1	-	-	-	-
52	-	-	-	1	-	-	-	-
53	-	-	-	-	1	-	-	-
54	-	-	-	-	2	-	-	-
55	-	-	-	-	-	-	-	-
56	-	-	-	-	-	-	-	-
57	-	-	-	-	-	-	-	-

APPENDIX 6.V.II

Gillnet selectivity: showing mean retention lengths (FL or TL in cm) for various commercial species of fish, caught in each mesh size. The standard deviation appears below each mean length together with the sample size in brackets.

Species	Stretched mesh size in inches								
	2	3	4	5	6	7	8	9	10
Hydrocynus (TL)	31.33 ±3.63 (446)	43.70 ±3.11 (463)	56.6 +11.0 (46)	65.3 ±11.5 (64)	70.5 ±6.0 (23)	73.1 ±8.1 (19)	64.1 +10.3 (7)	-	-
Citharinus (TL)	-	-	-	49.6 ±3.5 (14)	54.0 ±7.9 (19)	57.3 ±4.2 (48)	56.3 ±3.7 (96)	57.5 ±4.1 (5)	-
Distichodus (TL)	-	40.4 ±4.2 (8)	45.2 ±5.2 (17)	54.1 ±8.4 (9)	62.6 ±12.4 (10)	66.3 ±6.8 (12)	69.7 ±8.1 (16)	72.8 ±9.0 (4)	-
Labeo (TL)	26.78 ±4.14 (96)	37.57 ±3.62 (290)	50.58 ±4.50 (118)	59.10 ±5.40 (236)	66.01 ±4.11 (61)	70.13 ±5.82 (16)	70.9 ±7.1 (5)	-	-
Barbus bynni (FL)	21.54 ±3.33 (124)	28.26 ±3.83 (389)	35.97 ±4.42 (287)	42.45 ±5.61 (135)	47.48 ±5.87 (66)	54.19 ±7.32 (74)	56.09 ±5.56 (37)	59.9 ±1.5 (5)	56.5 (1)
Bagrus bayad (FL)	25.3 ±3.2 (9)	40.4 ±7.7 (24)	52.8 ±10.6 (61)	48.1 ±13.9 (44)	63.3 ±12.1 (23)	62.8 ±14.7 (20)	51.5 ±15.9 (23)	33.5 (1)	66.5 (2)
Synodontis schall (FL)	22.00 ±3.47 (509)	23.88 ±2.86 (1117)	26.93 +2.57 (647)	24.86 ±3.53 (639)	25.01 ±4.05 (51)	25.41 ±3.74 (32)	25.70 ±2.34 (20)	24.3 ±2.6 (4)	21.0 (2)
Schilbe (FL)	25.61 ±3.16 (270)	30.11 ±1.83 (278)	28.00 ±2.88 (10)	27.5 (1)	27.0 ±3.6 (6)	25.5 (1)	-	-	-
Lates niloticus (TL)	-	48.2 * ±25.8 * (5)	61.2 * ±28.4 * (12)	52.0 ±11.5 (47)	57.8 ±11.3 (50)	73.7 ±11.5 (90)	80.52 ±18.33 (201)	86.6 ±14.6 (51)	91.3 ±13.2 (8)
Lates longispinis (TL)	24.02 ±4.64 (446)	31.34 ±4.40 (249)	36.04 ±7.29 (91)	40.25 ±8.75 (20)	34.4 ±14.5 (11)	28.0 ±12.1 (6)	29.5 (2)	35.5 (1)	-

* Values rather high because of some large specimens breaking net twine and increasing effective mesh size.

CHAPTER 7

SHORE SURVEY

by
A.J.Hopson, B.J.Harbutt
and A.A.Q.R. McLeod

CONTENTS

INTRODUCTION

METHODS

MACROPHYTIC VEGETATION

ALGAL AND INVERTEBRATE SAMPLES

FOOT SEINE SURVEY

BEACH SEINE SURVEY

POPULATION DENSITIES OF LITTORAL FISH

SUMMARY

7. SHORE SURVEY

A J Hopson, A J D Ferguson, B J Harbott and A A Q R McLeod

INTRODUCTION

A detailed study was carried out during the period October 1974-October 1975 in marginal areas of the lake. The objectives were to assess the importance of the sub-littoral region in the overall ecology of the basin and to demonstrate patterns of distribution in inshore species of fish. Much of the survey was carried out in a series of separate safaris during which a land-based team examined 40-60 km stretches of the shore. For logistic reasons, it was not possible to sample either the precipitous coast to the south west and south of the lake between Meriar and Sirima, or the west shore from Eliye to Kerio. The northern fringe of the lake, including the Omo delta, lies in Ethiopia and was not included in the survey. Apart from those exceptions, the entire 780 km of coastline was examined in detail.

Survey stations were usually situated at intervals of 5-10 km along the shore. At each station, various types of gear (see Methods) were used to provide samples of fish, invertebrates and algae. Details of vegetation and topographical notes were also recorded. The latter formed a basis for the descriptions of coastal topography presented in Chapter 1.

During the present project, measurements of primary productivity were made at three littoral sites in the south of the lake. The results are reported in Chapter 2 (see page 130). As a follow-up to this work, a comparison was made between the standing crop of submerged macrophytes and fish biomass at an inshore site in Allia Bay. The results of this study are considered below.

METHODS

Smaller fish were collected in a foot seine measuring 4 metres in length and 1.2 metres deep, made of woven terylene, with an aperture size of 0.8 mm. The net was pulled up by a fisherman at each end who kept the lead line in contact with the bottom by placing his inner foot over the lower towing rope. Fish of a larger size were caught in a nylon beach seine, 45 metres in length, 3 metres deep, with a cod-end of 19 mm stretched mesh. The larger seine net was usually shot from an 18 foot cutter. Owing to the difficulty of operating a small boat on the exposed western shore north of Ferguson's Gulf, no hauls were made with the beach seine on this stretch of coast during the present survey, but data from four samples collected with the same net during 1973 have been incorporated in the results. Length, weight and sexual maturity data for beach seine catches were recorded for each species in the field, but collections of fish from foot seine catches were preserved for laboratory examination. Invertebrates were sampled with a 30 cm diameter conical townet with a mesh size of 120 m p i and with a square-framed hand net of 0.5 mm mesh. Collections of pebbles, rock scrapings and portions of macrophytes were preserved for subsequent algal examination.

On rocky coastlines, sites suitable for seine netting, particularly with the beach seine, were restricted to bays where the substrate was usually of shingle and small stones. The efficiency of the beach seine varied considerably from site to site depending on a combination of factors, including slope, substrate, the presence of obstructions, weather conditions and available manpower. For this reason, values of catch per effort have not been calculated for beach seine samples, and numbers and weight of each species have been expressed as percentagesof total catch. In the case of the foot seine, the sampling technique was more uniform and catch data are presented in terms of numbers per station (Figs. 7.1-14).

MACROPHYTIC VEGETATION

Compared with other major African lakes, marginal vegetation in Lake Turkana was very sparse and the number of species low. Submerged vegetation in the shore survey area was limited to a single species, Potamogeton pectinatus, although detached clumps of a second species, Ceratophyllum demersum, which occurs in the Omo delta, were occasionallyobserved floating in open water in northern areas. Potamogeton pectinatus was widely distributed on soft substrates in areas where the shore shelved gently, on the more sheltered eastern side of the lake. The submerged plant occupied a well defined zone in water from ca 0.5-2.0 metres deep. These beds of vegetation were usually only a few metres in width, but in sheltered localities with an almost level bottom, particularly in Allia Bay and in El Molo Bay, extensive areas up to several hundred metres in extent were observed. Potamogeton pectinatus was absent from most of the exposed west shore of the lake, but the plant was well established in sheltered situations on the south coast of Kerio Bay, in the lee of Lolibekai Point and in small bays at the tip of Longech Spit.

Emergent vegetation was also found, chiefly on low energy shores and in lagoons on high energy coastlines. The most widespread species was Sporabolus spicatus which commonly became established on the newly exposed margins of the lake during the post-flood period. With the onset of flooding in the following season, the grass was inundated. Sporabolus spicatus cover varied from sparsely scattered tussocks, often heavily grazed by stock, to extensive areas of flooded marsh found during the flood period in Ferguson's Gulf and in the Meriar regions of the lake.

Paspalidium germinatum was also widespread in more sheltered localities, particularly in the north eastern area of the lake where the plant was often lightly scattered in a well marked zone between the submerged P. pectinatus and the shore. Extensive patches of P. geminatum were observed in Ferguson's Gulf, and during the flood season the buoyant stems grew rapidly to keep pace with a rise in water level of over one metre.

Cyperus laevigatus occurred sparingly on shores throughout the lake, but Diplachne fusca was a much more localised species noted chiefly in the Allia Bay area and at Meriar. Other localised forms included Echinochloa sp. noted in the delta of the Kerio River, and two species of Cyperus, C. articulatus and C. imbricatus which were observed only on the shore north of Ilaret in the north east corner of the lake.

The status of Typha australis, the reedmace, on the margins of Lake Turkana has changed considerably over the last few years, probably as a result of the net fall in lake level. Up to 1970, this species was locally common in river mouth lagoons, from Kerio north to the Omo delta and southwards down the east coast to El Molo Bay. A narrow fringing zone of T. australis was often found on the shores of the open lake from Koobi Fora northwards, and more extensive beds occurred in the Todenyang area and on the open shore immediately north of Ferguson's Gulf. Since 1970, T. australis has disappeared from most areas and observations made during the shore survey indicate that it is now restricted chiefly to the vicinity of the Omo delta and to the Kerio delta.

Although macrophytic vegetation was comparatively scarce in Lake Turkana, its role in the ecology of inshore fish was important. Aquatic plants provided both cover from predators and shelter from wave action. The rich associations of epiphytic algae which developed on leaves and stems were a valuable food resource, particularly for Sarotherodon and Tilapia. Macrophytes were in some cases grazed directly by large fish, and it was noted that Alestes dentex regularly ingested large quantities of Potamogeton pectinatus.

There was marked interaction between fish and grazing animals, particularly domestic stock, in the inshore waters of Lake Turkana. During periods of drought, grazing pressure was heavy not only in areas fringing the lake but in the sub-littoral zone. Donkeys and cows were often observed in Ferguson's Gulf feeding on Paspalidium in water up to one metre deep, several hundred metres from the shore. Herdsmen in El Molo Bay regularly utilised Potamogeton as a cattle food. A more dramatic example of such competition is provided by the Sarotherodon fishery in Ferguson's Gulf where a reduction of grazing on marginal Sporabolus by stock during 1974-75 is thought to have led to a vast increase in fish production. The phenomenon is discussed at length in Chapter 11, page 1348.

ALGAL AND INVERTEBRATE SAMPLES

The distribution of algae in samples collected during the shore survey is discussed in Chapter 2 (see page 123). Records of invertebrates in shore samples are summarised in an annotated check list which appears in Main Appendix 1.

FOOT SEINE SURVEY

The foot seine chiefly caught fish of under 3 cm in length. Distribution charts for the various species involved are shown in Figures 7.1-14. The area of the open circles is proportional to the number of fish recorded at each station, which is considered to be an index of abundance.

Results indicate marked variation in habitat preference between the species involved. Sarotherodon niloticus occurred at the highest proportion of stations, and Alestes nurse and Engraulicypris stellae were also widely distributed on nearly all coastlines. Concentrations of S. niloticus tended to be greater in well sheltered situations such as Ferguson's Gulf, Kerio Bay and El Molo Bay (Fig. 7.12). A more marked preference for shelter is evident in Aplocheilichthys rudolfianus which was only sparsely distributed outside protected bays (Fig. 7.9). Engraulicypris stellae was abundant on exposed coastlines where the slop of the shore was relatively slight. The low catches of this species recorded in the Northern Sector, particularly on the east coast near Ilaret (Fig. 7.6) are in close agreement with data on offshore distribution (Chapter 8, Fig. 8.54). Results for A. nurse (Fig. 7.2) indicate high densities in the Turkwell Sector and in the Loiengalani area, suggesting that the predominantly coarse substrates in the region are particularly suitable for this fish.

Barilius niloticus shows a clear preference for hard substrates and was the commonest small fish on precipitous coastlines, both in the southern basin and on the main islands (Fig. 7.5). The species was also regularly observed on the sandy, high energy beaches to the west of the lake, but on the east shore none was recorded north of the basaltic shores of the Kakoi Horst. An antithetical pattern is apparent in Chelaethiops bibie, a species with similar food preferences which was common only on soft substrates at the northern end of the lake (Fig. 7.7). The distributions of the two species overlapped only on the west shore, north of Ferguson's Gulf.

Micralestes acutidens (Fig. 7.3) was less common than C. bibie but ranged over a similar area both inshore and offshore (see Chapter 8 , Figs. 8.52 and 8.55). The two species extended further southwards on the western shore than on the east, a pattern which may have been connected with the tendency for turbid waters to spread more extensively down the west shore of the lake during the flood season.

Haplochromis rudolfianus showed a preference for well vegetated sites and was most common in the vicinity of Potamogeton beds on the east coast (Fig. 7.11). The species was, however, recorded on the exposed west shore of the lake, living in the shelter of grassy vegetation in small lagoons protected by sand beds.

The young stages of larger fish were well represented in the more northerly stations. Concentrations were highest on the north east coast where juvenile Labeo horie, Alestes baremose, Lates spp. and Synodontis schall all occurred regularly. Labeo horie fry were particularly common in the area north of Ilaret. The same species of young fish were observed on the west coast, north of Ferguson's Gulf, but S. schall was rare, occurring at only two out of 29 stations (Fig. 7.8). Alestes baremose fry were not recorded south of Ferguson's Gulf, but early stages of L. horie and S. schall were both collected in the Kerio area where spawning is known to occur. Of these four larger forms, the fry of Lates spp. were most widespread, occurring at scattered stations throughout the southern region of the lake (Fig. 7.10).

Early stages of other major commercial species of fish were either recorded rarely or were completely absent from the foot seine samples. Schilbe uranoscopus of 2.5-3.0 cm were noted in the Ilaret and Kerio areas, Bagrus bayad of 2.1-3.1 cm were collected from three stations north of Ilaret, and two Citharinus citharus of 4.4 and 8.7 cm occurred in catches at Todenyang.

BEACH SEINE SURVEY

A total of 82 stations were sampled with the beach seine during the present investigations. For the purposes of analysis, the survey area has been divided into a total of 10 sections (Fig. 7.15) and data from sampling sites within each section have been combined. The results for each section are shown in Tables 7.1 a-j where percentage numbers and weights have been calculated for each species. A summary of the status of fish caught in six seine net hauls at Todenyang during 1973, for which numerical and weight data were incompletely recorded, is given in Table 7.2.

Sarotherodon niloticus was by far the most widespread species, occurring in 74 out of the 82 beach seine samples. The species dominated catches both in terms of weight and numbers in all sections on the eastern shore of the lake and on the west shore at Meriar. Relatively low numbers were recorded at the Longech sampling station which was situated in Ferguson's Gulf, close to the entrance. A detailed study of S. niloticus (see Chapter 11) shows that although the species was very abundant in the southern and central areas of the gulf, densities fell considerably in regions adjacent to the open lake. A very low proportion of S. niloticus occurred in catches on exposed sandy beaches in the West Coast section to the north of Longech. The size of S. niloticus in the beach seine catches ranged from 5-48 cm TL, but the majority lay between 15 and 25 cm.

Hydrocynus forskalii was also widely distributed and dominated catches at Longech and in the West Coast section particularly. There was a marked tendency for the relative importance both of this species and of Alestes baremose to fall in more southerly areas of the lake.

Labeo horie appeared regularly in beach seine samples and often formed an appreciable portion of the catch. A very high proportion were immature fish, less than 25 cm in length, and marginal areas of the lake appear to be the principal nursery grounds for this species. Most Lates niloticus were also small immature fish of below 35 cm TL but occasional large fish of up to 168 cm were caught in the beach seine.

Members of Clarias lazera were always low, but large individuals of up to 98 cm TL were regularly caught, particularly on the east shore of the lake, and the contribution made to the total weight of the catch was often relatively high. Bagrus bayad is principally a deepwater demersal species in Lake Turkana, but small numbers of both juveniles and adult fish were caught in most sections during the shore survey. Lates longispinis, another offshore species, was recorded only in the Ilaret section (Table 7.1b) where exceptionally turbid conditions prevailed in coastal waters during the sampling period. Synodontis schall appeared sparingly in samples over much of the area investigated.

The distributions of Sarotherodon galilaeus and Tilapia zillii reflected their preferences for soft and hard substrates respectively. Both species occurred on the east shore between from Allia Bay to Loiengalani where substrate types show considerable variation from mud to rock, but S. galilaeus alone was recorded from Meriar and Longech in areas of predominantly fine deposits.

Citharinus citharus was recorded only twice during the present survey, at Longech and in the Sandy Bay section on the east shore. The species was also noted in the 1973 catches at Todenyang (Table 7.2).

The species composition of beach seine catches varied remarkably little from section to section over most of the survey area. The limited data from exposed sandy beaches on the west coast indicate, however, that species diversity in such areas is generally much lower than was the case in sheltered situations. Results from the foot seine samples (Figs. 7.1-14) indicated that on high energy shores where small lagoons and bays are constantly formed and reformed by wave action and changes in lake level, there was often adequate food and cover for small fish and as a consequence the fauna was relatively rich compared with open beaches. It seems likely that H. forskalii, the dominant species on the high energy shorelines, preyed chiefly on lagoon based populations of small fish.

The presence of Heterotis niloticus, Polypterus senegalus and Auchenoglanis occidentalis in the most northerly sections (Tables 7.1a and 7.2) suggests that the inshore fauna of the delta region, beyond the northern boundary of the survey area, differed significantly from that of more typical regions of the lake.

POPULATION DENSITIES OF LITTORAL FISH

Quantitative estimates of fish abundance were not usually made during the shore survey, but data are available for a single trial carried out in Allia Bay from 24th to 28th February 1975. The trial was conducted with the object of estimating population densities of inshore fish and comparing them with the standing crop of the submerged macrophyte, Potamogeton pectinatus. An area of 30 m^2 on the fringes of an extensive bed of Potamogeton with an average depth of 73 cm was sampled with the aid of an ichthyotoxin. The fish were impounded within the area by means of a net of 10 mm stretched mesh which had been suspended above the perimeter on a framework of light poles 24 hours previously.

The wet weight of Potamogeton growing within the experimental area amounted to 32.4 kg, equivalent to a standing crop of 10,800 kg/ha. Samples of the macrophyte were dried to constant weight at 70° C, and a further estimate of 1933 kg/ha was obtained for biomass per unit area in terms of dry weight.

Population densities based on the numbers and weights of fish collected within the enclosure are presented in Table 7.3. Haplochromis rudolfianus and Alestes nurse were the dominant species both with regard to biomass and numbers, and together formed 87% by weight of the entire sample. Juveniles and adults of both forms were present in large numbers, indicating that the two species were habitual occupants of the macrophyte beds. Although no attempt has been made to provide lakewide estimates by extrapolating data from this single sampling site, results suggest that the biomass of small fish inhabiting the extensive beds of Potamogeton in Lake Turkana is comparatively high. The total biomass of 1089 kg/ha (Table 7.3) was considerably higher than values estimated for small offshore fish in metre townet catches, whereas at peak densities in the 10-20 m depth zone of the Northern Sector a mean population density of only 104 kg/ha was recorded.

SUMMARY

A survey of the onshore region of Lake Turkana was carried out between October 1974 and October 1975. Fish populations throughout the lake were sampled with a foot-seine of mosquito netting and with a beach-seine of 19 mm stretched mesh. Collections of invertebrates and algae were also made.

The macrophytic vegetation of the lake margin was sparse and Potamogeton pectinatus was the only widely distributed submerged species. Emergent vegetation was chiefly limited to two species of grass, Sporobolus spicatus and Paspalidium geminatum. Interaction between fish and animals grazing the lake shore was noted.

The distribution of littoral fish was related to substrate, shelter and the influence of inflow from the River Omo. *Sarotherodon niloticus* was the most widely distributed species occurring on all coastlines but less commonly in exposed situations. *Engraulicypris stellae* and *Alestes nurse* were also widespread. *Barilius niloticus* and *Tilapia zillii* showed a clear preference for coarse substrates and were common on rocky shores. *Haplochromis rudolfianus* and *Aplocheilichthys rudolfianus* were associated with marginal vegetation. The distribution of *Micralestes acutidens* and *Chelaethiops bibie* were limited to more northerly areas of the lake where the influence of the River Omo floodwater was greatest. Post-larva and early juveniles of several large species of fish, including *Alestes baremose*, *Labeo horie* and *Synodontis schall* were also chiefly found on the shores of the northern basin but the fry of *Lates* spp. ranged throughout the lake. *Hydrocynus forskalii* and *Lates niloticus* were the main onshore predators with the former occurring particularly commonly.

Quantitative assessments of onshore fish stocks were limited to a single experimental area in Allia Bay and a density of 1088 kg/ha was estimated in a *Potamogeton* bed, where *Haplochromis rudolfianus* and *Alestes nurse* were the principal species.

Algal and invertebrate samples are discussed elsewhere in the report.

TABLE 7.1 a

Summarising the results of hauls with the 50 metre x 19 mm mesh beach seine at 3 stations in the Banya section during October 1974 in the course of the shore survey. The number of weights of each species of fish are expressed as percentages of the total catch. The total weight is expressed in Kg.

Species	No. of stations at which recorded	% number	% weight
Polypteus senegalensis	1	+	1
Heterotis niloticus	1	+	6
Hydrocynus forskalii	2	18	4
Alestes baremose	3	20	1
Labeo horie	3	19	1
Auchenoglanis occidentialis	1	+	2
Bagrus bayad	1	3	8
Clarias lazera	1	+	1
Lates niloticus	1	2	7
Sarotherodon niloticus	3	38	68
TOTAL		327	47.8Kg

TABLE 7.1 b

Summary of shore seine data for 6 stations in the Ilaret sections during October 1974. Otherwise as Table 7.1 a

Species	No. of stations at which recorded	% number	% weight
Hydrocynus forskalii	6	21	12
Alestes baremose	6	27	2
Labeo horie	6	7	2
Bagrus bayad	4	1	5
Schilbe uranoscopus	1	+	+
Clarias lazera	2	1	4
Synodontis schall	3	1	1
Lates niloticus	4	2	37
Lates longispinis	3	1	2
Sarotherodon niloticus	6	39	35
TOTAL		634	101.2Kg

TABLE 7.1 c

Summary of shore seine data for 8 stations in the Kakoi-Koobi Fora section during the period October-December 1974. Otherwise as Table 7.1 a

Species	No. of stations at which recorded	% number	% weight
Hydrocynus forskalii	8	15	4
Alestes baremose	4	9	2
Alestes dentex	1	+	0
Labeo horie	6	9	5
Bagrus bayad	2	+	1
Clarias lazera	5	3	34
Synodontis schall	3	1	0
Lates niloticus	3	2	4
Sarotherodon niloticus	8	61	48
TOTAL		747	290Kg

TABLE 7.1 d

Summary of shore seine data for 7 stations in the Allia Bay section during 1974 and 1975. Otherwise as Table 7.1 a

Species	No. of stations at which recorded	% number	% weight
Hydrocynus forskalii	5	4	9
Labeo horie	3	3	5
Barbus bynni	1	+	0
Bagrus bayad	2	+	4
Clarias lazera	2	1	22
Synodontis schall	3	3	4
Lates niloticus	4	+	2
Sarotherodon niloticus	7	55	44
Sarotherodon galilaeus	3	1	1
Tilapia zillii	4	33	9
TOTAL		1781	150Kg

TABLE 7.1 e

Summary of shore seine data for 11 stations in the Allia to Moite section during August 1975. Otherwise as Table 7.1 a

Species	No. of stations at which recorded	% number	% weight
Hydrocynus forskalii	10	11	7
Alestes baremose	3	14	6
Labeo horie	8	6	7
Synodontis schall	1	+	+
Lates niloticus	2	+	3
Sarotherodon niloticus	10	66	76
Sarotherodon galilaeus	3	1	+
Tilapia zillii	1	+	+
TOTAL		886	22Kg

TABLE 7.1 f

Summary of shore seine data for 11 stations in the Moite to Porr section during January 1975. Otherwise as Table 7.1 a

Species	No. of stations at which recorded	% number	% weight
Hydrocynus forskalii	9	3	2
Alestes baremose	3	4	4
Alestes dentex	2	+	2
Citharinus citharus	1	+	1
Labeo horie	8	16	8
Synodontis schall	1	+	+
Lates niloticus	9	3	21
Sarotherodon niloticus	11	70	44
Sarotherodon galilaeus	3	2	17
Tilapia zillii	3	2	1
TOTAL		1586	141Kg

TABLE 7.1 g

Summary of shore seine data for 5 stations in the El Molo to Loiengalani section during the period January 1975. Otherwise as Table 7.1 a

Species	No. of stations at which recorded	% number	% weight
Hydrocynus forskalii	4	3	7
Labeo horie	1	1	2
Bagrus bayad	1	+	2
Clarias lazera	1	1	26
Synodontis schall	2	1	7
Lates niloticus	1	1	1
Sarotherodon niloticus	5	64	41
Sarotherodon galilaeus	3	6	7
Tilapia zillii	5	23	9
TOTAL			

TABLE 7.1 h
Summary of shore seine data for 5 stations in the Meriar section during March 1975. Otherwise as Table 7.1 a

Species	No. of stations at which recorded	% number	% weight
Hydrocynus forskalii	3	1	1
Alestes baremose	1	+	1
Labeo horie	4	9	23
Bagrus bayad	1	+	1
Clarias lazera	1	+	2
Lates niloticus	3	+	+
Sarotherodon niloticus	4	72	63
Sarotherodon galilaeus	5	12	9
Tetraodon fahaka	1	+	+
TOTAL		2188	84Kg

TABLE 7.1 i
Summary of shore seine data for 19 samples taken in Met Bay during the period 28/4/73 to 28/6/74. Otherwise as Table 7.1 a

Species	No. of stations at which recorded	% number	% weight
Hydrocynus forskalii	15	32	29
Alestes baremose	11	23	8
Alestes nurse	1	14	1
Citharinus citharus	2	+	+
Labeo horie	12	9	8
Clarias lazera	3	+	3
Chrysichthys auratus	5	+	+
Schilbe uranoscopus	2	+	+
Bagrus bayad	14	4	8
Synodontis schall	13	6	8
Lates niloticus	7	+	27
Sarotherodon niloticus	15	11	7
Sarotherodon galilaeus	4	+	+
Tetraodon fahaka	1	+	+
TOTAL		4137	703Kg

TABLE 7.1 j

Summary of shore seine data for 4 stations on the West Coast, at Namudak, Nachakiu, Kataboi and Lowarangak, during the period May to September 1973. Otherwise as in Table 7.1 a

Species	No. of stations at which recorded	% number	% weight
Hydrocynus forskalii	4	86	91
Alestes baremose	3	6	4
Bagrus bayad	1	1	2
Synodontis schall	1	2	2
Sarotherodon niloticus	2	5	2
TOTAL			

TABLE 7.2

Summary of fish caught at Todenyang in five hauls with a seine net of 5 inch stretched mesh, and one haul with the standard shore seine, during the period 1973-1974

Species	Status
Polypterus senegalensis	occasional
Heterotis niloticus	occasional
Hydrocynus forskalii	frequent
Alestes baremose	frequent
Citharinus citharus	occasional
Bagrus bayad	frequent
Clarias lazera	frequent
Synodontis schall	occasional
Sarotherodon niloticus	common

TABLE 7.3

Estimated population densities of species of fish occurring in a bed of *Potamogeton pectinatus* in Allia Bay, based on an experimental area of $32m^2$ smpled by icthyotoxin in February, 1975.

Species	Size range (mm)	No/ha	kg/ha
Alestes nurse	14-62	$5.1x10^5$	386.0
Engraulicypris stellae	11-38	$6.3x10^4$	10.1
Bagrus bayad	43	$3.3x10^2$	0.1
Synodontis schall	22-25	$1.0x10^3$	0.9
Aplocheilichthys rudolfianus	11-34	$1.2x10^4$	2.6
Haplochromis rudolfianus	3-79	$4.8x10^5$	558.0
Lates niloticus	8-54	$6.0x10^3$	3.5
Sarotherodon niloticus	16-126	$3.1x10^4$	127.9
TOTAL			1088.9

CHAPTER 8

OPENWATER SURVEYS

by

A. J. Hopson, J. Hopson,
A.A.Q.R. McLeod and M.G. Pawson

CONTENTS

INTRODUCTION

BOTTOM TRAWL SURVEY

MIDWATER TRAWL SURVEY

FRAME TRAWL SURVEY

METRE TOWNET SURVEY

GILLNET SURVEY

THE PHOTOENVIRONMENT AND PATTERNS OF MIGRATION AND DISTRIBUTION IN OPENWATER FISH

APPRAISAL OF THE OPENWATER SURVEY RESULTS

REFERENCES

INTRODUCTION

The surveys which form the basis of this chapter concern fish living in the main body of the lake beyond the confines of the littoral region, at depths greater than about 3 m. A high proportion of the work was carried out from R V HALCYON and due to the danger of fouling gillnets, the commercial fishing grounds situated near the west shore at depths of less than 10-15 m (see Fig. 6. **2b**) were generally excluded from the present investigaations. The commercial fishing areas are considered at length in Chapter 6.

The objectives of the open water surveys have been to establish how the various species of fish are distributed and to provide estimates of stock density. The latter are essential for the predictions of potential yields. Migrations, both short-term and long-term have also been investigated. Due to the wide variation in size and differences in habits of fish it was not possible to obtain the necessary data using a single type of gear and a number of different nets including trawls, townets and gillnets have been employed. A special feature has been the use of acoustic survey gear to augment and expand results obtained by more traditional methods. The acoustic gear has enabled rapid lakewide surveys to be made several times during the course of a year and has provided a clear picture of the pattern of stock density distribution.

BOTTOM TRAWL SURVEY

A J Hopson and A A Q R McLeod

INTRODUCTION

METHODS

RESULTS

Location of stations

Species composition of bottom trawl catches

Catch per effort

Analyses of bottom trawl catches by depth and locality

Analyses of bottom trawl catches by depth and season

Estimates of standing stock

COMPARISON WITH OTHER MAJOR AFRICAN LAKES

SUMMARY

INTRODUCTION

The present survey was carried out between May 1972 and November 1975 with the object of estimating the stocks of demersal fish in Lake Turkana and to investigate how the abundance of fish varied with depth, region and season. Bottom trawling proved to be the most effective method of sampling such fish, and in the course of the investigations a total of 385 hauls was made covering over 85% of the total area of the lake. Areas where trawling was impracticable fell into three categories: (a) inshore areas within the 3 metre contour where navigation was impossible or dangerous - (b) commercial fishing grounds which lay chiefly within the 15 metre contour on the west coast between Ferguson's Gulf and the Omo delta (Fig. 6.2b), where the presence of extensive fleets of gillnets precluded tawling - and (c) limited areas mainly in the Southern Sector of the lake where rough substrates of rocks or stones endangered the gear.

Echo recorders show that during the hours of daylight demersal fish were concentrated in a well defined layer within 4 metres of the lake bed (Fig. 8.75). In this layer densities of fish tended to increase towards the bottom. The nets used during the present survey had headline heights of up to 3 m and were thus capable of sampling a high proportion of demersal fish.

Bottom trawl catches provided much of the material on which detailed biological studies of fish have been based. A monthly sampling programme was maintained in the Ferguson's Gulf area throughout the period of investigation with the object of providing such study material and in addition the catch data has provided a valuable supplement to the survey results.

A total of 60 bottom trawl hauls were made concurrently with Triton echo survey readings. Correlations between echo integrals and the trawl catches have been used to calibrate the Triton equipment (see page). The results of the Triton survey (see page) provide a synoptic view of demersal fish distribution in the lake, and should be interpreted in conjunction with the findings of the present trawl survey.

METHODS

Trawling was carried out exclusively from R V HALCYON, a 50 ft research vessel powered by a Kelvin T6 180 hp engine (see Main Appendix 2). Three nets, all manufactured by Messrs Bridport Gundry Ltd, Aberdeen, were used for the survey.

(a) A 24 metre headrope 'Victoria' two-seam bottom trawl made up with polythene twine to specifications provided by BERGSTRAND and CORDONE (1971) who used a similar net for their survey of Lake Victoria. The net was provided with a cod end of 38 mm stretched mesh. The effective fishing width of the net was approximately 9 metres with a headline height of 2.3 metres (BERGSTRAND and CORDONE, op. cit.). The 'Victoria' trawl was used for a total of 149 hauls during the period May 1972 to June 1973.

(b) A 29 metre headrope 3-bridled trawl also constructed of polythene twine, manufactured by Mess Bridport Gundry, Aberdeen. The net was fitted with a 38 mm cod end previously in use on the 'Victoria' trawl. During initial trails with the 3-bridled trawl the skipper found it impossible to obtain equal tension on all bridles, and for this reason the middle pair of bridles was removed. Although used exclusively with two pairs of bridles, it is still referred to as the 3-bridled trawl. The effective fishing width was approximately 10 metres with a headline height of 3 metres. A total of 225 hauls was made with this net during the period June 1973 to November 1975.

(c) A 29 metre headrope 'Danish Fish Trawl' constructed of black nylon twine. This net was used for a total of only 11 hauls during June 1974. It was fitted with a 38 mm cod end transferred from the 3-bridled trawl.

The bottom trawls were towed on sweeps of 38 mm circ. polypropylene 6-strand combination wire rope 55 metres in length. Wooden otter-boards of 152 x 84 cm were used for the first 226 hauls including all hauls with the 'Victoria' net, and 77 hauls with the 3-bridled trawl. During October 1973 the wooden boards were replaced with 183 x 102 cm steel vee-form doors which were in use for the remainder of the survey.

Towing time, which is defined as the duration of the tow from squaring up of warps to the commencement of hauling-in, varied from 10 minutes to 120 minutes but the great majority of hauls were concluded after a tow of 30 minutes. A speed of approximately 3 knots (5.5 km/hr) was maintained during the tow. The ratio warp length: lake depth varied from approximately 5-6:1 in shallow waaer to as little as 3:1 in the deepest parts of the lake below the 80 m contour. Catches were found to vary significantly with depth, and in order to achieve maximum possible homogeneity within a sample, tows were usually made parallel to the depth contours.

During hauling-in, warps and sweeps were wound onto the winch drums. The bridles were then lifted manually onto the powerblock which was used to haul the bulk of the net inboard. Once alongside, the cod-end was lifted over the stern by means of tackle suspended from an A-frame. The catch was sorted into species and weighed prior to the recording of length frequencies and collection of biological data from individual fish.

Details of each bottom trawl haul were noted on a separate sheet. The information included position, gear parameters, lake depth, climatic conditions and a summary of the catch. These data were later transferred to punch cards which formed the basis for the detailed analyses of results presented below. Position was usually fixed at the commencement of a tow by means of the ship's radar which had a maximum range of 44 km. In a few cases, when the radar was out of action, a sextant was used to obtain the co-ordinates. Grid references for each station were derived from the East Africa Grid. The 10 km x 10 km squares of the East Africa Grid were also used as census squares in analyses of fish distribution, and were identified by a simplified system of rows A-Z running from north to south, and columns 1-11 running from west to east (Fig. 8.1).

Catch per effort was expressed as kilogrammes per 1 hr trawling time (kg/hr). The efficiency of the 'Victoria' trawl and the '3-bridled ' trawl was found to differ considerably. It was not possible to conduct parallel trials on the two trawls due to the poor condition of the older net. However, results showed that Bagrus bayad was comparatively uniformly distributed within each depth zone in the Central Sector of the lake, although densities increased with depth. By comparing the mean values for tows with each net in each zone (Table 8.1) an overall mean of 1:1.43 was obtained for the ratio between catch per effort of B. bayad in the 'Victoria' trawl and in the 3-bridled trawl. A correction factor of 1.43 was subsequently applied to all values of catch per effort calculated for the 'Victoria' trawl. Catch per effort in the bottom trawl analyses which appear below is thus expressed in terms of 3-bridled trawl catch. The higher efficiency of the 3-bridled trawl is due partly to the wider gape of the net and partly to the increased headline height. Hauls made with the Danish fish trawl are too few for detailed comparisons to be made, and for the purposes of the present survey its catching efficiency is assumed to be the same as the 3-bridled trawl.

Values of catch per effort used in the present chapter were based on weights recorded in the field. For more detailed analyses of catch per effort which are included in biological studies of various fish (see Chapters 9 to 11), weights were derived from length frequencies. Data for each species at each station were converted into numbers per hour for each 5 cm length group. Length/weight constants were then used to transform the frequency into weight per hour for each 5 cm length group.

Climatic conditions on the lake were often severe, particularly during the mornings, and wind speeds in excess of 70 kph were recorded frequently (see page 29). As a rule wave conditions became too severe for fishing when wind speed exceeded 40 kph and in consequence the trawl survey was often restricted to the calmer afternoon period.

Nearly all tows were made during the daytime owing to the difficulty of navigation on the lake after dark, particularly in areas where Turkana gillnets were likely to be encountered. Results from four night-time bottom trawl hauls indicate that as the result of a movement of fish away from the lake bed after dark, catches were considerably lower than in daylight. Data from night hauls were not used in the analyses which appear below. Certain other hauls were considered to be non-quantitative and were also omitted from the analyses. These included tows in which the gear was caught on an obstruction or was damaged, and tows where fish were required live for tagging or for acoustic experiments. A complete schedule of all bottom trawl tows is presented in Table 8.2.

A fine bag of 19 mm stretched mesh was attached to the outside of the cod end for a total of 19 quantitative hauls. Catches from the fine bag are not included in results for the main net. Apart from providing valuable data on smaller size groups, the fine bag samples enabled mesh selectivity of the 38 mm mesh cod end to be investigated. Sufficient data were available for the mean selection length (50 percent point) to be calculated for the following species:

Species	selection point for 38 mm cod end
Bagrus bayad	8 cm FL
Lates longispinis	7 cm TL
Haplochromis macconneli	6 cm TL

There is no evidence to indicate the escapement of a significant proportion of the largest fish from bottom trawls, and catches included *Lates niloticus* up to 190 cm TL, the maximum size recorded for any species in the lake. The results indicate that bottom trawls caught random samples of fish at all sizes above a minimum length of approximately 10 cm. Such fish occurring within the physical limits of the bottom trawl survey area constitute the trawlable stock of the lake.

RESULTS

LOCATION OF STATIONS

Figure 8.2 illustrates the distribution of the 341 quantitative hauls made with the bottom trawl during the course of the present investigations. High densities of stations near Longech Spit and Central Island are due to the regular monthly sampling of material for biological investigations which continued in this region throughout the survey period. Certain areas were inadequately surveyed for various reasons. Thus in the extreme north, the lake was too shallow for HALCYON to operate safely, and the sampling of inshore areas on the west coast between Ferguson's Gulf and the Omo delta was prevented by the presence of commercial gillnets. East of South Island the rough nature of the lake bed made bottom trawling impracticable. Apart from such omissions, the major ecological areas of the open lake were adequately covered by the survey programme. Table 8.3 shows a breakdown of quantitative hauls by depth zone, together with an estimate of the area of the lake bed lying within each zone. The proportion of hauls made in each zone corresponds reasonably closely to the relative area.

SPECIES COMPOSITION OF BOTTOM TRAWL CATCH

The species composition of quantitative catches is shown in Table 8.4 where data for the 341 hauls have been combined. The percentages do not represent the true proportions of the various fish in the trawlable stock of the lake since sampling was biased in favour of particular areas. Further errors are introduced by the variable duration of towing time. Such bias is corrected in the analyses which follow. Table 8.4, however, provides a reasonable introduction to the composition of bottom trawl catches. The predominance of four species, _Bagrus bayad_, _Synodontis schall_, _Lates longispinis_ and _L. niloticus_ is obvious. They together form over 85% of the total catch. At the opposite extreme _Citharinus citharus_, _Clarias lazera_, _Malapterurus electricus_ and _Sarotherodon galilaeus_ were each represented by only a single individual. The virtual absence of _C. citharus_ from bottom trawl catches was surprising since during the initial year of the trawl survey, this species still formed 20% by weight of the total commercial catch (see Chapter 6, page 362). It would appear that _C. citharus_ was restricted to the commercial fishing grounds on the west shore of the northern basin, and to other shallow areas outside the scope of the present survey where small numbers were recorded in experimental gillnets (see page 361). _Clarias lazera_ and _S. galilaeus_ were also confined to shallow marginal waters of the lake but _M. electricus_ was probably rare in all lacustrine environments. Certain species such as _Barbus turkanae_, _Chrysichthys auratus_ and _Haplochromis macconneli_ were caught commonly in bottom trawl tows under the appropriate environmental conditions but due to small size, their contribution to the total weight was only slight.

CATCH PER EFFORT

Total catch per effort for the 341 quantitative hauls varied from zero catch on one occasion to a maximum of 2200 kg/hr with an overall mean of 230 kg/hr. The frequency distribution of catches per effort is illustrated by the histograms in Figure 8.3. The upper histogram in which the data are plotted arithmetically suggests a negative binomial distribution. This is confirmed in the lower histogram where a $\log_{10}(x + 1)$ transformation has resulted in an approximately symmetrical distribution agreeing closely with the fitted normal distribution curve.

Mean catch per effort in kg/hr for each species and for each of nine depth zones covering the whole survey area is shown in Table 8.5. Coefficients of variation (Table 8.6) have been calculated for the sample data on which the mean values in Table 8.5 were based using the following expression:

$$\text{Coefficient of variation} = \frac{(\text{Standard deviation about mean x } 100\%)}{\text{Mean}}$$

For a completely uniform distribution, standard deviation = 0 and CV = 0%. Increasing values of CV thus indicate increasing irregularity of distribution. Table 8.6 proves that _Bagrus bayad_ was the most evenly distributed species, particularly in deeper water where a marked tendency for lower values of CV is evident. Values of CV were generally higher in other species and varied from depth zone to depth zone without showing any definite trends.

ANALYSIS OF BOTTOM TRAWL CATCHES BY DEPTH AND LOCALITY

In Figure 8.4 results are analysed for each species on the basis of depth and locality with the lake divided transversely into six sections. The most northerly section consists of rows A-D of the census grid (Fig. 8.1). The remaining sections are formed by rows E-G, H-K, L-M, N-R, and S-Y respectively. A total of 12 depth zones has been recognised. The shallow zones are at 5 metre intervals and the deeper zones at 10 metre intervals with all catches from below the 80 metre contour grouped into a single zone.

The most comprehensive results were obtained from rows L-M which include the Longech Spit and Central Island areas in the Central Sector of the lake. Highest values of mean catch per effort for total catch were recorded between 5 and 30 metres with a peak between 15 and 20 metres. Three of the four predominant species, Synodontis schall, Lates longispinis and L. niloticus reached a peak in the same depth zone which for much of the year corresponded to the inshore limit of the midwater scattering layer. A similar peak is evident in Hydrocynus forskalii and the maximum for Schilbe uranoscopus occurred in slightly deeper water. All five species are important predators of small pelagic Alestes which are the principal components of the scattering layer. Relatively low catches were recorded in rows L-M for Labeo horie and Distichodus niloticus, both important inshore species restricted chiefly to shallower water within the 20 metre contour. Sarotherodon niloticus, which is principally a littoral species in Lake Turkana, was noted only as a rare straggler at depths between 10 and 30 m. Most species became progressively more uncommon below the 30 metre contour but Bagrus bayad increased steadily offshore to reach a peak in the deepest part of the lake. A similar increase in catches of Haplochromis macconneli and Barbus turkanae is masked by the low weight contribution of these small fish. It seems probable that most of the species which appear to spread offshore from centres of distribution in shallower water, such as H. forskalii, S. uranoscopus, S. schall and L. longispinis, were actually situated in the surface or midwater layers, and were caught in the deeper areas of the lake during the shooting or recovery of the trawl. Barbus bynni, however, is a benthic feeder and although peak catches were recorded in shallow water, the deeper water records probably represent fish feeding on the bottom.

Results from other areas of the lake (Fig. 8.4) generally show trends similar to those observed in rows L-M although a number of local variations are evident. Due to smaller sample size the pattern of distribution often appears more irregular. Notable differences in the inshore catches of B. bayad were probably correlated with turbidity. In the extreme north (rows B-D), where the water is often highly turbid, comparatively high catches were recorded close inshore. This is in contrast to rows H-K where inshore data were derived chiefly from Allia Bay. Limnological evidence (see Chapter 1, page 52) has shown that the Allia Bay area, unlike most parts of the northern basin, remains free from turbid flood water throughout the year. Comparatively high transparencies probably explain why the distribution of B. bayad in rows H-K is similar to the pattern observed in the clear southern waters of the Lake (rows N-X) with very low catches in shallow water. Figure 8.4 reveals that other species are influenced by transparency in a similar way. In the case of Sarotherodon niloticus, which is chiefly sub-littoral in distribution, significant catches were only recorded in those areas with low turbidity.

The highest catches of Lates niloticus were normally found in shallower water (Fig. 8.4) but the peak value for any depth zone was recorded at a depth of 25-30 metres in the extreme north (rows B-D). One of the two samples on which the value was based was a 15 minute tow which included 22 large L. niloticus from a localised spawning concentration.

It is surprising to find that with the exception of B. bayad and L. niloticus no marked increase in catch per effort at the northern end of the lake is evident from Figure 8.4. This is in noticeble contrast to results for smaller fish caught in townet and frame trawl samples in which significantly higher concentrations were recorded in the northern sector (see below).

Changes in catch per effort and species composition with depth and locality are summarised in the pie diagram presented in Figure 8.5.

ANALYSIS OF BOTTOM TRAWL CATCHES BY DEPTH AND SEASON

Detailed analysis of seasonal changes in bottom trawl catches with depth has been limited to data from grid rows H-O in the Central Sector of the lake (Fig. 8.6). Results from the four years were pooled and mean values of catch per effort were calculated for three 4-month periods, November to February, March to June and June to October, corresponding to the post-flood, pre-flood and flood seasons. As in the regional analyses discussed previously a total of twelve depth zones were recognised over the area as a whole. Fish distribution within the 15 metre contour in the Allia Bay area (rows H-K columns 5 and 6) differed markedly from the pattern observed elsewhere and the data have been treated separately (Fig. 8.6).

Results from the main area investigated (Fig. 8.6) indicate that the basic paattern of depth distribution changes relatively little during the course of a year. A tendency for populations to move seasonally inshore and offshore is, however, discernable in several species including B. bayad, S. schall and L. longispinis. As a general rule mean catch per effort in zones within the 20 m contour rose during the post-flood period. This inshore movement appears to be correlated with the influx of turbid Omo flood water which reached the vicinity of Ferguson's Gulf during the first half of September each year. Mean catch per effort had fallen significantly in shallower water by the period March to June, when transparency reached an annual peak in the Central Sector of the lake.

Figure 8.6 indicates that for most species of fish, population densities over the main area as a whole remained relatively constant throughout the year. Schilbe uranoscopus, however, showed definite seasonality with minimum catches occurring during the flood season when biological data indicate that the adult population migrate away from the main lake to spawn in the major rivers (see Chapter 10, page 1055 Records from the Allia Bay area are not available for the pre-flood season but mean catches of both B. bynni and S. schall were considerably higher in the flood season than in the post-flood season. It is possible that the high flood season catches represented an influx of fish from more northerly areas of the lake where seasonally high turbidities may have affected normal behavioural patterns.

Seasonal changes in total catch per effort for bottom trawls over the whole lake are illustrated by distribution charts (Fig. 8.7 a, b, c). Each tow is represented by a circle, the area of which is proportional to the catch per effort. Similar distribution charts for individual species of fish appear in Figures 8.8 and 8.17.

ESTIMATES OF STANDING STOCK

Results from the bottom trawl survey have provided a basis for the estimation of standing stock following principles laid down by ALVERSON and PEREYRA (1969). The basic assumption is that a linear relationship exists between catch per effort and that portion of the standing stock which is susceptible to capture by the trawl. Stock densities are readily calculated if the area sampled by the trawl during a standard tow is known. Thus:

$$\overline{Pw} = \overline{(C_w/f)}\ (A/_{c\bar{a}})$$

where $\overline{Pw}$ = mean standing stock in weight of exploitable population inhabiting area A; $\overline{C_w}$ = mean catch in weight; f = fishing effort; $\bar{a}$ = average area sampled during standard tow; c = coefficient of vulnerability.

Sampling 'area' in fact includes that area of the bottom lying in the path of the trawl together with the adjacent depth slice actually sampled by the net. The coefficient of vulnerability is a measure of the efficiency of the gear and is the product of two coefficients, c_h which relates to the efficiency of the net with regard to fish lying within its actual path, and c_v relating to the efficiency of the net with regard to fish distributed over the entire water column within the verticals to the path of the net.

Specifications provided by the manufacturers of the 3-bridled trawl used during the present survey indicate that the net has a spread of 10 m in the fishing position. Measurements made with a headline transducer showed that the maximum headline height during fishing was 3 metres. Tows were made at a standard speed of 5.5 km/h (3 knots) and the area sampled during a tow lasting one hour was thus 0.055 km^2. Since no information is available regarding the behaviour of fish lying in the path of the trawl, it is assumed that the value of coefficient c_h is unity. For the purposes of the preliminary analysis c_v is also taken as unity.

By inserting the above gear parameters in the equation it was possible to calculate standing stock/km^2 for each depth zone in each of the six sub-sectors (grid rows A-D, E-G, H-K, L-M, N-R, and S-Y) from mean values of catch per effort for individual species. The resultant areal densities were then multiplied by the area of the lake occupied by the appropriate depth zone and totals from the various zones were summed to provide a lakewide total for each species shown in the final column of Table 8.7. The table also shows mean areal densities for the three main sectors and for the entire lake, derived from the subsectional data.

The accuracy of the estimates varies considerably from zone to zone and from species to species. Errors were particularly serious in inshore areas where, as mentioned previously, there was unavoidable sampling bias in the 0-10 m depth zone leading to the gross under-representation of valuable commercial species such as *Sarotherodon niloticus*, *Citharinus citharus*, *Distichodus niloticus* and, to a lesser extent, *Labeo horie* and *Barbus bynni* in trawl catches. For this reason a further analysis has been made for depths greater than 10 m where it is considered that the survey provided a more accurate estimate of trawlable stock (Table 8.8).

Further errors in the preliminary estimates accrued from the tendency of open water fish to disperse through the water column with a proportion of the population situated in the midwater layers above the headline of the bottom trawl. As noted above, coefficient c_v provides a correction for such errors in cases where the proportion of fish passing over the headrope is known. During the present investigations, frame trawl hauls carried out in the Longech Spit area yielded detailed information on the vertical distribution of fish, discussed at length on page 604. The results show that the fraction of the population located in the midwater layers varied considerably from species to species and with lake depth. Thus in deeper water beyond the 30 metre contour several important species including *Schilbe uranoscopus*, *Synodontis schall* and *Lates longispinis* tended to be fully pelagic, occurring away from the bottom (see Fig. 8.34). In shallower water, however, the same species were relatively evenly distributed throughout the lower part of the water column from the midwater scattering layer to the bottom (see Figs. 8.31-33). From frame trawl data it was possible to calculate relative densities of fish (expressed as gm/horizontal tow of 1 hour) for:

(a) The midwater layers from the midwater scattering layer downwards but excluding the bottom 3 metres

(b) The bottom 3 metres

The results are shown in Table 8.18. If it is assumed that the relative densities of fish in the bottom and midwater layers (Table 8.18) were characteristic of the shallow regions of the lake, and that midwater fish were distributed evenly between the bottom layer and the scattering layer, then it is possible to calculate c_v for each depth zone and each species:

$$c_v = \frac{(c_b/f)}{\left[d(\overline{c_m}/f)\right] + (\overline{c_b}/f)}$$

where $(\overline{c_b}/f)$ = mean catch per effort for frame trawl on bottom; c_m/f = mean catch per effort for frame trawl in midwater layers; v = vertical height of frame trawl; d = vertical depth over which midwater fish are distributed evenly above the bottom layer.

The expression has been used to calculate the values of c_v for different species, depth zones and sectors shown in Table 8.9. Allowances have been made for the variations in the mean depth of the scattering layer between different sectors of the lake and thus midwater fish were assumed to be distributed evenly below depths of 7.5 metres in the Northern Sector, 12.5 m in the Central Sector and 17.5 m in the Southern Sector. Calculations, following the procedure above, were made for depth zones down to a maximum of 25 m in the north, 30 m in the Central Sector, and 40 m in the south. In deeper water it is likely that a high proportion of midwater fish were caught in the bottom trawl during shooting and hauling, but attempts to calculate c_v based on estimates of volumes sampled by the ascending and descending net lead to grossly exaggerated figures. In consequence values of c_v from the outermost shallow water zones have been repeated in each of the deeper zones (Table 8.9). Although this may have led to underestimation, evidence from pelagic surveys and from echo readings confirm that the biomass of midwater fish falls considerably in deeper offshore areas. Such inaccuracies would thus lead to comparatively minor errors in the overall estimate of standing stock.

Frame trawl data for Bagrus bayad and Haplochromis macconneli prove that these species are principally demersal in distribution and usually extend only slightly above the depth zone sampled by the bottom trawl. In consequence the value of d has been maintained at 3 m for all depths in these species.

Relatively few Lates niloticus were caught in the frame trawl samples and results were biased by the large size of individual fish. The midwater distribution of this species is probably similar to L. longispinis and values of c_v for the latter have been applied to L. niloticus (Table 8.9). A similar procedure has also been followed for Barbus bynni in the absence of adequate data.

Corrected estimates of standing stock (Table 8.10) which allow for the midwater distribution of fish have been calculated in the same way as the preliminary estimates, but with values of c_v from Table 8.9 substituted in the equation.

No attempt has been made to correct data for the principal surface species, Hydrocynus forskalii and Alestes baremose, and errors in the standing stock estimates are certainly high, particulary in the latter species. The majority of such surface fish were probably secured in the course of shooting and hauling the trawl, even at moderate depths. There was always a lengthy period during the shackling and unshackling of the otter boards when the trawl continued to fish on the surface. It is also believed that Alestes baremose was confined to the top four metres of the water column and exhibited fright reaction to the passage of the ship resulting in the escape of a high proportion of fish from the path of the net. With so many variables, estimates for the two surface species are not quantitative and they have been omitted from the estimated total in Table 8.31.

The provisional estimates (Tables 8.7 and 8.8) which consider only fish situated within the path of the trawl, may be regarded as a measure of trawlable standing stock, whereas the corrected estimates (Table 8.10) relate to total biomass less that portion of fish which by virtue of size escape from the gear.

The present data have been used to provide yield estimates in the final chapter.

COMPARISON WITH OTHER MAJOR AFRICAN LAKES

BERGSTRAND and CORDONE (1971) have provided comparable data for a detailed trawl survey of Lake Victoria. In the discussion which follows, values of catch per effort quoted in their report have been corrected by a factor of 1.47 to allow for the lower catching power of their standard gear, a 'Victoria' bottom trawl (see Table 8.1

above). A mean catch per effort equivalent to 600 kg/hr was recorded for a total of 232 hauls made throughout Lake Victoria at all depths with a 38 mm cod end. During the present survey a mean value of 230 kg/hr was recorded for 341 hauls in Lake Turkana using comparable gear. Over 80% by weight of fish in the Lake Victoria catch were cichlids, principally Haplochromis spp. Cichlids were of little importance in the area covered by the present survey except in shallow water close to the east shore. Non-cichlids usually contributed over 99% by weight of the Lake Turkana samples.

In Lake Victoria catches fell steeply offshore between the 60 and 80 m contours mainly as a result of decreases in the abundance of Haplochromis spp. Densities of Bagrus docmac also fell abruptly from over 45 kg/hr in water shallower than 60 m to 0.4 kg/hr in the 70-79 m zone. Relatively high catches were maintained in the deepest waters of Lake Turkana as the result of an increase in the abundance of Bagrus bayad with depth. Definite ecological preferences were apparent in the two Bagrus spp occurring in Lake Turkana with B. bayad ubiquitously distributed on soft substrates and B. docmac restricted to the few tows made on rocky bottoms. In Lake Victoria where B. bayad does not occur, B. docmac ranged widely over soft mud.

Synodontis victoriae was the only fish in Lake Victoria which increased markedly in deeper water, reaching peak abundance beyond the 50 m contour. A strikingly different situation was observed in Lake Turkana where Synodontis schall was generally abundant in shallow water and became rare in bottom trawl catches at depths greater than 40 m. Comparable intralacustrine depth differences are also evident in Clarias spp. Clarias lazera is strictly littoral in Lake Turkana and was recorded only once in trawl catches, whereas Clarias mossambicus occurred regularly at all depths in Lake Victoria.

The results of a comprehensive bottom trawl survey of the southern end of Lake Malawi have been analysed by TURNER (1977). Differences in gear, mesh size and towing speed prevent direct comparison with data from the present survey. A mean trawlable standing stock of 7.9 tonnes/km^2 was recorded in Lake Malawi for the section of the survey area shallower than 100 m, compared with 3.3 tonnes/km^2 in Lake Turkana. Values of catch per effort declined steadily with depth in both lakes. As in Lake Victoria, small cichlids formed a high proportion of the catch in Lake Malawi. A bagrid, in this case B. meridionalis, was again a regular component of the demersal stock, reaching peak catch rates between 30 and 60 m but falling to a minimum below the 80 m contour where small cichlids continued to predominate.

SUMMARY

A total of 341 quantitative bottom trawl samples were made throughout Lake Turkana between May 1972 and November 1975. The results have been analysed on the basis of depth, season and locality.

Marked changes in the species composition of the catch with depth were found, with the major commercial species Sarotherodon niloticus and Labeo horie restricted to inshore areas of the lake and Bagrus bayad becoming increasingly predominant in deeper water offshore. Lates niloticus, L. longispinis and Synodontis schall were the most important species at intermediate depths.

The results were used to estimate the standing stock of demersal fish in the lake. Corrections were also applied to the results to allow for the pelagic distribution of species such as L. niloticus, L. longispinis and S. schall.

MIDWATER TRAWL SURVEY

A J Hopson and A A Q R McLeod

INTRODUCTION

METHODS

RESULTS

Sampling stations

Vertical zonation of open water fish

Horizontal distribution of open water fish

SUMMARY

INTRODUCTION

Surveys with midwater trawls were initiated to provide information on stocks of pelagic fish which were known to occur within the lake. Attention was directed particularly to the midwater scattering layer first observed in Lake Turkana by HOLNESS (1969). The layer is a characteristic feature of the open waters of the lake, appearing on echo charts as a densely stippled band several metres in vertical extent and often divided horizontally into two (see Fig. 8.18). The position of the trace varies in the water column from within the top 5 metres to a depth of more than 20 metres depending on turbidity (see page 599). It was originally thought that the trace was formed by a midwater concentration of commercial-sized fish, but the results of the present investigations show that the principal fish involved are Alestes minutus of 2-3 cm in length.

The objectives of the present survey were to investigate the distribution of pelagic fish on a lakewide basis, to study the vertical zonation of fish, particularly with regard to the midwater scattering layer and to provide estimates of the biomass of the species concerned. In practice, the frame trawl (see page 603) proved to be a more effective net than the midwater trawls for sampling fish populations in relatively narrow depth layers.

METHODS

Two mid-water trawls were used from R V HALCYON during the present investigations.

(a) A 26 metre headrope nylon Engels net manufactured by Mess Bridport Gundry Ltd of Aberdeen with a 38 mm stretched mesh cod end. The net was fished in conjunction with the 55 metre sweeps and 152 x 84 cm otter boards normally in use with the bottom trawls (see page 506). During initial trials Kelvin tubes were used to measure the headline height and the gape of the net. A Kelvin Hughes 80 ohm headline transducer connected to the ship's MS44 echo sounder was subsequently fitted.

A total of 63 midwater hauls was made with the Engels net during the period May 1972 to May 1973, but in most cases records of fishing depth and gape proved to be inadequate. As a result, no quantiative analyses of data from this net have been made.

(b) A 24 metre headrope terylene midwater trawl manufactured by the Boris Net Co Ltd, Fleetwood and fitted with a cod end of 19 mm stretched mesh. The net was designed to fish with a square opening 10 m wide and 10 m high, and such an opening was achieved in practice. Suberkrub pelagic otter boards 183 cm high and 86 cm wide were used exclusively with this gear together with sweeps of 38 mm circ. combination ropes. The upper and lower sweeps were 33 and 35 metres in length respectively. 60 kg lead weights were shackled to the attachment between each of the lower sweeps and bridles. Buoyancy was provided by four 'Polyform' cylindrical fenders 60 cm long by 20 cm diameter attached to the headrope. The gear was equipped with 80 ohm Kelvin Hughes headline transducer firing downwards, linked to the ship's MS44 echo sounder.

Survey routine followed the pattern described above for the bottom trawl, but additional readings were obtained from the echo sounder relating to headline depth and vertical gape of the net. The majority of tows were of 30 minutes duration at a speed of 3 knots (5.5 km/hr). Larger fish were weighed and measured immediately after capture, but Alestes spp and other small fish were preserved for subsequent examination in the laboratory.

A total of 101 hauls was made with the Boris net during the period September-November 1975. Initially, fishing was confined to the Ferguson's Gulf-Central Island area, where a series of horizontal hauls was carried out at various depths throughout the water column. During October and early November 1975 a lakewide survey was conducted with the aid of this gear. At each station, one 30 minute haul was made in the top 10 metres with the object of sampling the surface community and, where applicable, a second 30 minute haul was made in the depth zone occupied by the midwater scattering layer. Simultaneous readings of echo density within the sampling layer were logged, using the Simrad Echo Integrator (see page 626) with the object of obtaining a correlation between catch per effort and echo integral. In practice it was found that the relatively turbid conditions prevalent during the late flood season in the northern part of the lake were far from ideal. Under such conditions the midwater scattering layer was at times situated within the top five metres, rendering any distinction between midwater and surface communities impossible. Moreover, 5 metres is the minimum range at which the Triton echo sounder (linked to the Simrad Integrator) will operate effectively, and when the midwater scattering layer was close to the surface it was impossible to obtain integral readings.

A summary of hauls made with the Boris midwater trawl is given in Table 8.11. Although the sampling was always directed towards a particular depth zone, fish from other layers entered the net during shooting and hauling.

RESULTS

SAMPLING STATIONS

The positions of Boris midwater trawl stations are indicated in Figure 8.19. As mentioned previously, two hauls were made at many stations, particularly in more southerly areas where the midwater scattering layer was situated below the top 10 metres. The upper depth limit of the midwater scattering layer during the October-November 1975 survey period is shown in Figure 8.20. A steady southward increase in depth is clearly seen. East-west gradients in the Central Sector of the lake, with the scattering layer relatively deeper near the eastern shore, closely parallel the pattern revealed by light penetration data (Chapter 1, page 52) in which higher transparencies were recorded near the east shore.

THE VERTICAL ZONATION OF OPEN WATER FISH

Quantitative data from 81 hauls made in all areas of the lake have been analysed on the basis of the depth zones listed in Table 8.11. There has been considerable overlap between layers in the catches due to the large mouth opening of the net, with numerous tows sampling both the surface and the midwater scattering layers. Catch per effort is quoted in No/hr as well as in kg/hr since at the gain settings used on echo sounders in Lake Turkana, it was the smaller fish occurring in large numbers which were responsible for a high percentage of the midwater echo traces under investigation. The results are presented in Tables 8.12 to 8.15. A summary of all numerical data is given in Table 8.16.

There is strong evidence to show that Alestes minutus, mostly of 2-3 cm FL, were the principal constituents of the midwater scattering layer. This species greatly outnumbered other fish in all depth zones but reached a peak in scattering layer samples. It is likely that the majority of A. minutus included in Boris trawl catches from other depth layers were caught in the scattering layer during shooting and hauling. The species never formed more than 14.1% of the mean total weight of fish caught in any depth zone (Tables 8.12 to 8.15) but it is certain that a relatively high proportion of A. minutus escaped through the 19 mm stretched mesh cod end (see page 605).

Several other species including Hydrocynus forskalii, Alestes ferox, Schilbe uranoscopus and Lates longispinis similarly reached peak numbers in the midwater scattering layer (Table 8.14) and supporting evidence from other gear suggests that all, with the exception of H. forskalii are principally midwater in distribution; Hydrocynus forskalii normally reaches maximum abundance in the surface layers. Alestes baremose, another characteristic surface form, was recorded in peak numbers in the top 10 metres (Table 8.12), but was also noted in samples from the scattering layer. The highest catches of Synodontis schall were recorded in the pelagic zone below the scattering layer, where only 5 out of 81 quantitative samples were taken. It seems likely that the abundance of this species is considerably underestimated by results from the Boris midwater survey as a whole. In a total of 47 midwater tows with the Engel's trawl between May and December 1972, S. schall was the predominant fish forming 31% by weight of the total catch.

The two principal offshore demersal species, Bagrus bayad and Haplochromis macconneli were both numerous in the single haul made with the Boris net on the bottom (Table 8.16) but occurred only rarely in other depth zones. The prawn Macrobrachium niloticum was widely distributed throughout the midwater layers down to the lake bed.

The values of catch per effort for each depth zone sampled by the Boris midwater trawl provide an indication of the relative densities of the species concerned. No attempt has been made to derive total biomass for the midwater areas of the lake since the degree of overlap between depth zones and the proportion of catch sampled outside a selected depth layer would be difficult to account for. It is considered that values derived from oblique frame trawl hauls provide a more satisfactory basis for the estimation of total biomass of midwater fish (see below).

THE HORIZONTAL DISTRIBUTION OF OPEN WATER FISH

The lakewide distribution of various species of fish in the Boris midwater trawl catches during the period mid-September to mid-November 1975 is illustrated in Figures 8.21-8.29. For species occurring chiefly in subsurface water, data from samples which include the midwater scattering layer have been used, but in the case of Hydrocynus forskalii and Alestes baremose the distribution in surface catches was plotted. Lates niloticus and Sarotherodon niloticus records from all Boris trawl stations were incorporated in Figure 8.29.

Although the pattern of distribution varies considerably from species to species, a common trend is discernable in three midwater fish, Alestes ferox, A. minutus and Lates longispinis (Figs. 8.23, 8.24 and 8.28). In this group the highest catches were generally located near the west shore between North Island and Kerio Bay. Relatively high catches were also recorded on the east shore from Koobi Fora northwards, but the data indicate low densities in the more transparent waters of the Allia Bay area, both inshore and in mid lake. Although no fish were caught at the most southerly stations, the three species extended further south than other forms. Areas where relatively high densities of the three species were encountered correspond with localities where the echo traces of the midwater scattering layer were generally heavy.

The occurrence of Schilbe uranoscopus and Synodontis schall (Figs. 8.25 and 8.27) in the midwater catches was limited chiefly to the west side of the lake, particularly from the region of North Island northwards and between Longech Spit and the vicinity of Eliye. A markedly different distribution was noted in Alestes baremose (Fig. 8.22) with catches occurring chiefly in the more transparent waters of the east coast of the lake. Hydrocynus forskalii ranged widely throughout, and apart from zero catches in the extreme south, regional variations in catch per effort were relatively slight. The occurrence of single Sarotherodon niloticus at three stations in the north of the survey area indicates that this species was distributed in small numbers in open water in this region, possibly in the course of dispersal movements between inshore sites. Lates niloticus was recorded infrequently, principally at inshore stations on both east and west coasts from a line between Longech and Allia southwards.

SUMMARY

Details of two types of midwater trawl used on Lake Turkana are provided. The most comprehensive results were obtained in a survey with a Boris midwater trawl during the period September-November 1975 in the course of which 81 quantitative hauls were made, throughout the lake, in water deeper than 10 metres. Investigations were limited chiefly to the surface areas and to the midwater scattering layer. In the northern half of the survey area the scattering layer was situated near the surface and the two layers were sampled simultaneously.

Alestes minutus was the predominant species occurring in the midwater scattering layer together with smaller numbers of *Hydrocynus forskalii*, *A. ferox*, *Synodontis schall* and *Schilbe uranoscopus*.

Charts are provided to illustrate the distribution of the most important species of fish. *Alestes minutus*, *A. ferox* and *Lates longispinis* shared a similar pattern with peak numbers generally near the western shore. *Alestes baremose* tended to occur more commonly near the east shore and *Hydrocynus forskalii* ranged throughout. The results indicate a dearth of pelagic fish in the southern basin of the lake.

FRAME TRAWL SURVEY

A J Hopson and A A Q R McLeod

INTRODUCTION

METHODS

RESULTS

Sampling stations
The vertical zonation of open water fish
Diel changes in vertical migration
The horizontal distribution of open water fish
Estimates of total biomass

SUMMARY

INTRODUCTION

The frame trawl, with a square mouth opening of 2.8 x 2.8 m, was designed to sample midwater fish within a relatively narrow depth layer. In spite of its small size, the gear was capable of catching fish over a size range similar to that of midwater trawl catches (using an identical mesh size) including *Lates niloticus* up to 110 cm TL. The rapidity with which the net could be shot and hauled was a particularly useful feature which enabled a series of samples to be collected within a comparatively short period of time. The principal investigations carried out with the aid of the frame trawl were:

(a) Studies of the vertical zonation of fish in the open waters of the lake with particular reference to the midwater scattering layer

(b) Diel changes in the vertical distribution of open water fish

(c) Lakewide variations in the distribution of open water fish

METHODS

The frame trawl (Fig. 8.30) consisted of a roughly conical bag, 8 metres in length and of 19 mm stretched mesh nylon netting. The net was laced to a square welded frame of 102 mm diameter steel piping measuring 2.8 x 2.8 m. Two bridles each 1.8 metres in length were attached to the vertical members of the frame 0.8 m from each of the upper corners. Two 22 kg Scripps depressors suspended on chains from the lower corners held the frame in a vertical position in the water. The trawl was controlled from the main winch by a single warp which was payed out over the stern of R V HALCYON through a snatch block attached to the A-frame. An 80 ohm Kelvin Hughes headline transducer linked to the ship's MS 44 echo sounder and firing upwards was attached to the top of the net.

Techniques for shooting the frame trawl varied. Where horizontal hauls in a particular depth zone were required, the gear was lowered at the maximum possible speed until a predetermined length of warp was indicated on the warpmeter. Final adjustments to depth were made after the headline transducer trace indicated that the net depth had stabilised. Horizontal hauls at a speed of approximately 3 knots (5.5 kph) usually lasted either 10 or 15 minutes at the end of which the net was retrieved at the maximum possible winch speed. Results indicate that shooting and hauling at speed prevented the capture of fish outside the sampling layer during descent or ascent. The high speeds also enabled tows to be made in rapid succession and it was usually possible to collect four 10 minute samples from a depth of 20-30 metres within an hour.

An alternative procedure was followed during lakewide surveys of openwater fish. Double oblique hauls from surface to bottom and back were made at each station with the warps payed out and recovered at a low winch speed of approximately 4.5 m/min. In this way an integrated sample of fish from the entire water column was obtained.

Routine data for frame trawl catches were recorded using the procedure described previously for bottom and midwater trawls. Catch per effort for horizontal hauls was expressed in both No/hr and gm/hr. In the case of oblique hauls a different system was employed using catch per standard haul (kg/SH). A standard haul is defined as a full water column haul in which 1 metre of depth is sampled (the net moving either up or down) for every 10 metres of movement in a horizontal direction. Time and speed parameters were used to calculate the horizontal distance for each tow and a standard haul factor was calculated as follows:

$$\text{standard haul factor} = \frac{\text{horizontal distance}}{\text{vertical distance}} \times 0.1$$

The standard haul factor was then applied to the weight of each species caught to give catch per standard haul. This value is a measure of catch per unit lake area and for the frame trawl with a mouth opening of 7.48 m^2 a catch of 1 kg/SH is equivalent to an areal density of 1.27 kg/100 m^2 .

RESULTS

SAMPLING STATIONS

A summary of samples carried out during the course of frame trawl surveys is given in Table 8.17. The location of oblique frame trawls made during lakewide cruises is evident from the distribution charts for individual species (Figs. 8.36-42).

THE VERTICAL ZONATION OF OPENWATER FISH

Four separate series of frame trawl data relating to vertical zonation during the hours of daylight have been analysed (Table 8.17). In each case sampling was carried out in open water immediately to the east of Longech Spit.

The most comprehensive results were obtained during April-May 1974 (Fig. 8.31). Echo records indicated that the midwater scattering layer was situated at a depth of 10-18 metres, varying as a result of local patches of more turbid water in the area. The numerical results (Fig. 8.31) show that an overwhelming concentration of fish, consisting almost entirely of *Alestes ferox* and *A. minutus*, coincided with the depth of the midwater scattering layer. Below the scattering layer numbers were relatively low, but a moderate increase occurred on the bottom mainly due to the presence of the prawn *Macrobrachium niloticum*. Densities of those species present in the surface layers were minimal.

Results expressed in gm/hr (Fig. 8.31) demonstrate more clearly the vertical distribution of other species. *Hydrocynus forskalii* occurred at all depths but tended to concentrate in the surface layers. *Lates longispinia* also ranged widely from just below the surface layers to the bottom where maximum weights were recorded. Low densities of *Schilbe uranoscopus* were recorded in the midwater scattering layer and this species was found in appreciable quantities only in the deepest zones where *Bagrus bayad* also formed a significant proportion of the biomass. Other species confined to the bottom layers were *Barbus bynni* *B. turkanae*, *Chrysichthys auratus* and *Haplochromis macconneli*. Peak catches of *Synodontis schall* were recorded in the upper midwater scattering layer where total catch almost equalled that of the bottom zone.

Investigations during July-August 1975 were restricted to the midwater layers. The midwater scattering layer was situated at a depth of between 12 and 20 metres and the limited results (Fig. 8.32) are in close agreement with April-May 1974 data discussed above. *Alestes minutus* was by far the most abundant species with peak numbers occurring in the lower region of the scattering layer. As in the previous observations *S. schall* made an important contribution to the weight of fish caught in the scattering layer, together with the small *Alestes* spp.

The two remaining series of observations (Figs. 8.33 and 8.34) were made during September-December 1973 when, due to comparatively turbid conditions, the midwater scattering layer was situated at a depth of between 4 and 10 metres in the Ferguson's Gulf area. The notable dearth of *Alestes minutus* in these samples is thought to be due to a seasonal decrease in the mean length of the population following peak spawning which resulted in the escapement of a high proportion of smaller fish through the 19 mm stretched mesh. Apart from the scarcity of *A. minutus*, the vertical zonation of fish in the shallow water series (Fig. 8.33) was basically similar to the pattern described above, but with the midwater fish extending further towards the surface. *Alestes ferox* was the most numerous species in samples from the region of the midwater scattering layer but the presence of several *Lates niloticus* weighing up to 13 kg biased catch per effort expressed in terms of weight in favour of this species. Catches of *Synodontis schall* were consistently high throughout the midwater layers but none was caught on the bottom, indicating that the species was entirely pelagic during the sampling period in this particular area of the lake. *Schilbe uranoscopus* and *L. longispinis* were well distributed through the midwater region from the scattering layer to the bottom. Both species had tended to concentrate nearer the bottom during April-May 1974 (Fig. 8.31). *Bagrus bayad*, *H. macconneli* and *B. turkanae* were again confined to samples on or near the bottom and, as in previous series, *A. baremose* occurred only in hauls from the surface layers.

Results for the offshore series (Fig. 8.34) shows that in deeper water a number of species, which in shallower regions occurred near the bottom, were fully pelagic in distribution. Alestes ferox was again the most numerous species in the midwater scattering layer but moderate numbers of S. schall, S. uranoscopus and L. longispinis, representing a relatively high biomass, were also taken in midwater samples from the scattering layer down to a depth of about 20 metres. The water column between a depth of 20 metres and the bottom was inadequately sampled but the frame trawl data indicate that population densities of fish within the size range under consideration were low in this region. A similar inference was drawn from echo survey data. Catches of fish noted in surface and bottom samples (Fig. 8.34) were in each case similar in composition to the catches from comparable depths in the shallower water series discussed above (Fig. 8.33).

Table 8.18 compares catches of fish occurring in the water column below the midwater scattering layer but excluding the bottom 3 m, with samples from the latter depth zone. These data have been used in the calculation of c for bottom trawl stock density estimates (see page 592).

DIEL CHANGES IN VERTICAL ZONATION

During April 9th and 10th 1974 a series of seven 10 minute frame trawl hauls was repeated five times during a twenty four hour period with the object of investigating diel changes in the vertical distribution of fish. The study was carried out in the open lake approximately 2.5 km east of Longech Spit at a depth of 27 m. The hauls in each series were made at depth intervals of 4 m thus covering the whole water column. Sampling was carried out at the following times:

Date	Time (EAT)	Series
9/4/74	13.15-15.05 hrs	Day
9/4/74	17.10-19.06 hrs	Dusk
9-10/4/74	22.50-01.58 hrs	Night
10/4/74	06.28-08.28 hrs	Dawn
10/4/74	11.00-12.55 hrs	Day

Echo traces showed that during full daylight the scattering layer was situated at a depth of approximately 13-18 metres.

The results, with catch per effort for each sample expressed in gm/hr, are illustrated in Figure 8.35. Most species exhibit a common behaviour pattern with a well marked migration towards the surface at dusk and a movement in the reverse direction at dawn. The small Alestes spp. which form the midwater scattering layer thus migrated approximately 12 metres upwards into the surface layers at night (Fig. 8.35). The prawn Macrobrachium niloticum was concentrated on or near the bottom during the day but tended to spread out evenly over the entire water column, with the exception of the top 4 metres, after dark. Other species situated near the bottom by day, including Lates longispinis, Schilbe uranoscopus and Chrysichthys auratus, similarly extended their range towards the surface, although to a lesser extent, so that their position relative to the smaller Alestes remained unchanged. Nocturnal movements in Bagrus bayad and B. bynni followed the same general pattern, but these fish were almost exclusively limited to the bottom 12 metres of the water column. None of the other species occurring in the survey area exhibited such a regular diel cycle of behaviour. Alestes baremose was recorded only from the top 4 metres and Haplochromis macconneli was restricted to the bottom. Hydrocynus forskalii and Synodontis schall were distributed more irregularly and the results are difficult to interpret. During calm evenings large shoals of H. forskalii were often seen breaking the surface of Lake Turkana and such behaviour was noted during the sampling period. The presence of H. forskalii in the surface layers at dusk (Fig. 8.35) probably represents surface shoaling. The concentration of this species in the middle of the water column at night suggests that a marked downward migration occurred after darkness had fallen.

THE HORIZONTAL DISTRIBUTION OF OPEN WATER FISH

The oblique frame trawl hauls on which these observations are based were made during two separate cruises, the first in late July 1974 covering the entire lake, and the second during early September 1975 restricted to the northern half. Similar results were obtained where the two surveys overlapped and data have been combined. A summary of catch data from the total of 62 hauls is presented in Table 8.19. Catch per effort has been expressed in number and weight per standard haul (see Methods above). An estimate of population density in kg/km^2 is also provided, based on the assumption that an equivalent surface area of 78.4 m^2 is sampled during a standard haul.

Bagrus bayad made up approximately half of the total catch per effort by weight and Alestes minutus formed a similar proportion of the total catch expressed in terms of numbers. Alestes minutus was also the most widespread species, occurring at 41 out of the 62 sampling stations. The most important midwater species in terms of biomass were Synodontis schall, Lates longispinis and Schilbe uranoscopus followed by Alestes ferox and A. minutus. It is certain that the population density of A. minutus has been underestimated since, as with the Boris midwater trawl (see above), the small size of this fish would result in a significant proportion of the catch escaping through the 19 mm stretched mesh netting. Values for Bagrus bayad also underestimate the total population since although the species reaches a fork length of 80 cm, the maximum size recorded in the frame trawl was only 41.5 cm FL. Such size selectivity may have been due to a failure of the frame trawl to sample hard down on the bottom or to avoidance resulting from the configuration of the net.

The distribution of fish in the oblique frame trawl hauls is shown in Figures 8.36 to 8.41. The sampling period coincided with the earlier half of the flood season when the influx of turbid water from the River Omo was concentrated in a broad tongue down the west coast, extending past North Island into the Central Sector (see Chapter 1, page 45). Results for total catch (Fig. 8.42) indicate that the highest densities of fish tended to occur within this sediment plume. Distribution charts for individual species (Figs. 8.36 to 8.41) show that in all cases comparatively large catches were recorded within the same area, including offshore species such as Bagrus bayad, Barbus turkanae and Haplochromis macconneli which normally occur in deeper water. It seems likely that this pattern of distribution was seasonal. Bottom trawl data indicate that with increasing transparency in the non-flood season demersal species tend to withdrawn into deeper water (see page 591).

All species were more abundant in the northern half of the lake than in the south, and this was particularly noticeable in *Alestes ferox* and *A. minutus*. Demersal species dominated catches in the extreme south.

ESTIMATES OF TOTAL BIOMASS

Biomass for the most important species of fish occurring in the frame trawl has been calculated (Table 8.20) from the estimates of density given in Table 8.19. It is assumed that the survey area includes all sections of the lake deeper than 5 metres, a total area of 6750 km . As mentioned above, it is likely that the values for *A. minutus* and *B. bayad* are underestimates. Comparable estimates from bottom trawl and metre townet surveys appear on pages 592 and 617 respectively.

SUMMARY

A 2.8 x 2.8 m frame trawl was used to provide information on both the vertical distribution and lakewide range of fish, principally pelagic forms.

The results demonstrate the vertical zonation of fish with *Hydrocynus forskalii* and *Alestes baremose* occurring chiefly in the surface layers, *Alestes minutus* and *A. ferox* forming the midwater scattering layer and *Bagrus bayad* and *Haplochromis macconneli* restricted to the bottom. Other pelagic forms including *Schilbe uranoscopus*, *Synodontis schall* and *Lates longispinis* range between the scattering layer and the bottom in coastal waters but tend to be entirely pelagic in deeper offshore regions.

Patterns of diel migration were demonstrated in nearly all species, with the exception of *Alestes baremose* and *Haplochromis macconneli*, and a general tendency for fish and large prawns to migrate towards the surface after dark was observed.

Results from oblique frame trawls sampling the full water column were used to determine the pattern of lakewide distribution of various species and to provide estimates of areal densities.

METRE TOWNET SURVEY

A J Hopson, J Hopson and A A Q R McLeod

INTRODUCTION

METHODS

RESULTS

Sampling stations

Vertical zonation of open water forms

Diel changes in the vertical zonation of smaller pelagic species

The horizontal distribution of openwater forms

Estimates of total biomass for species occurring in metre townet catches

SUMMARY

INTRODUCTION

Metre townets were used to sample fish up to a maximum size of 5 cm in the open waters of the lake. Catches included all size groups of small pelagic species such as *Alestes minutus* and *Engraulicypris stellae*, and post-larvae and early juvenile stages of larger fish including *Lates* spp and *Labeo horie*. Investigations with this type of net followed a similar plan to the frame trawl studies described above, and fell into two main categories.

(a) Studies of vertical zonation in which each depth zone was sampled separately

(b) Studies of lakewide distribution where each station was sampled with a double oblique haul ranging through the entire water column.

METHODS

Standard Marine Biological Association (UK) conical townets, 1 metre in diameter at the mouth, fabricated of woven terylene with an aperture size of 0.8 mm were used throughout the survey period. Several methods of rigging were used:

Rig 1: the net was fitted to a ring of 19 mm diameter round steel or steel piping with two welded lugs situated diametrically in relation to one another. The towing warp was attached directly to one lug and the net was pulled into a vertical position by a 22 kg Scripps depressor shackled to the second lug. During initial trials with the net Kelvin tubes were used to establish the maximum depth attained during a haul. Sampling depth was then plotted against warp length to produce a calibration curve on which subsequent positioning of the net was based. Rig 1 was used from June 1972 to December 1973.

Rig 2: similar to Rig 1 but with a V-shaped loop of piping projecting back horizontally from the top of the mouth ring on either side of the towing lug. The loop provided a platform for a headline transducer directed upwards. With the aid of the headline transducer it was possible to gauge the depth of the net more accurately. This rig was used for oblique hauls from January 1974 onwards.

Rig 3: designed to enable opening and closing of the net to be controlled remotely at any depth. The warp was shackled to the lower lug of the mouth ring from which was suspended a specially constructed steel vane on a wire 1.5 m in length (Fig. 8.43). The vane was fitted with a horizontal platform to which an upward firing headline transducer was attached. A 22 kg Scripps depressor was fixed below. Clamped onto the main warp approximately 105 cm from the end was a GO Model 4020 double trip unit. The second slot of the unit was used to secure the top of the mouth ring of the net during sampling with the aid of an 8 cm strop, eye spliced at both ends and shackled to the top lug of the net. The first slot was used to hold a loop on the end of a short length of cord wrapped round and securing the furled net. The net was equipped with a throttle cord running through a series of plastic rings approximately half way between the mouth and the cod end. A drogue was attached to the end of the throttle cord which was also held in the second slot of the double trip unit by means of an intermediate eye. During the initial stages of a tow the tension created by the drogue was thus prevented from throttling the net. The furled net was lowered to the required depth on the 4 mm hydrographic warp and a messenger was used to activate the double trip unit causing the first slot to open, thus releasing the net. On completing a sample a further messenger was dropped to trip the second slot, which resulted in the mouth ring falling away from the warp into a horizontal position. At the same time, tension provided by the drogue throttled the net which was then recoverd. A calibrated GO Model 2030 flowmeter was secured with a cord stretched across the mouth opening of the net.

Metre townets were worked from a boom situated amidships and projecting approximately 1.5 m over the starboard side of R V HALCYON at a height of 3 metres above the water. The warp was payed out through a 23 cm snatch block suspended from the boom. Most hauls were made with the 4 mm hydrographic warp, but for oblique hauls one of the main trawl warps was sometimes used. Towing speed usually lay within a range of 2.7 to 3.1 knots (5.0-5.7 kph).

Oblique metre townet hauls followed the pattern described previously for frame trawl hauls with the net sampling from surface to bottom and back at a relatively low warp speed of about 15 m/min. A different procedure was used with the opening/closing net (Rig 3) where samples were required from a depth layer of several metres in extent. Under such circumstances, a series of short down and up oblique hauls were made within the required depth range for a period of approximately 10 minutes. The net was then closed and recovered.

All material was preserved for subsequent examination in the laboratory. With large samples total numbers of each species were estimated by volumetric subsampling, and weights were calculated from length frequency distributions using length/weight formulae. For oblique catches, catch per effort was expressed in terms of numbers and weights per standard haul. As with the frame trawl, a standard haul was defined as a full water column tow in which the net travelled vertically through one metre for every 10 metres of horizontal motion. Standard haul factors were calculated for each tow and applied as a correction to the catch data (see page 609).

The mean filtering efficiency of the metre townet was estimated from flowmeter data to be 87.5% and the mouth area of the net was 0.79 m^2. Thus for oblique tows a catch of 1 kg/SH was equivalent to an areal density of 14.5 kg/100 m^2.

In the case of opening/closing net samples, the volume sampled was obtained from flowmeter readings and catches per effort were expressed both as concentrations (No or kg/100 m^3) and as areal densities (No or kg/100 m^2).

RESULTS

SAMPLING STATIONS

Metre townet samples are summarised in Table 8.21. The positions of oblique townet samples during the three seasonal analysis periods are indicated on the distribution charts (Figs. 8.49-60).

THE VERTICAL ZONATION OF OPEN WATER FORMS

The opening/closing metre townet (see Rig 3 above) was used for the investigation of vertical zonation of smaller open water species. The observations were carried out in the vicinity of Longech Spit and on a transect of the lake from the spit to the south end of Allia Bay. Relatively few small pelagic species occurred in this part of the lake and the samples usually contained a maximum of three species of fish, *Engraulicypris stellae*, *Alestes minutus* and the post-larvae of *Lates* spp. together with two prawns, *Caridina nilotica* and *Macrobrachium niloticum*.

The first series of observations were made during the daytime in open water east of Longech Spit at a lake depth of ca 50 m on February 6th and 7th 1975. Echo records showed that a relatively indistinct scattering layer was situated at a depth of 10 to 15 metres. A total of 8 depth zones were sampled:

0 - 1 m
1 - 5 m
5 - 10 m
10 - 15 m
15 - 20 m
20 - 30 m
30 - 40 m
40 - 50 m

The results are shown in Figure 8.44. Catch per effort is expressed in both mg/100 m^3 and No/100 m^3 and the area of each depth bar is thus proportional to biomass or total number.

Engraulicypris stellae and the prawn *Macrobrachium niloticum* were the most important species in terms of biomass and number, both tending to concentrate in the midwater layers between the midwater scattering layer and the bottom. A break in the vertical distribution of the two species at a depth of 10-15 m, coinciding with the position of the mid-water scattering layer, is significant. This feature was noted in all comparable series of samples. The evidence suggests that *Engraulicypris stellae* and *M. niloticum* together with *C. nilotica* tend to avoid the scattering layer in which, as demonstrated by frame trawl data, their potential predators Alestes minutus and A. ferox concentrate. The proportion of Alestes spp. caught during the present series was low (Fig. 8.44) but maximum biomass of the two species was in fact recorded at 10-15 m. Above the scattering layer the prawn C. nilotica predominated, occurring most abundantly between 5 and 10 m but with comparatively high densities at 1-4 m. All species were either rare or absent from the top metre indicating that a narrow surface layer was sparsely populated. Post larvae of Lates spp. and Labeo horie were represented in the samples. Lates extended throughout the water column, but the number of Labeo horie was too small for conclusions to be drawn regarding their vertical distribution. Engraulicypris stellae and the two species of prawns tended to increase markedly in size with depth. This phenomenon is analysed more fully below.

A second series of observtions were made during late February 1975 on an east west transect of the lake between Longech Spit and the south end of Allia Bay. A total of 7 stations were investigated with lake depth ranging from 7 to 84 metres. The number of tows varied from one at the shallowest station to nine at the deepest. In the top 30 metres the depth zones sampled were identical with those of the previous series (see above). Below 30 m, intervals of 20 metres (30-50 m, 50-70 m, 70-90 m) were sampled where applicable. During the course of each tow, echo integrals from the depth layer sampled were recorded on the Triton echo survey gear. Echo records showed that the midwater scattering layer was relatively light and situated at a depth of between 10 and 20 m.

The results are illustrated in Figure 8.45 a, b and c. Catch per effort in both No/100 m^3 and mg/100 m^3 has been calculated separately for each of three size groups in the major species. It is evident from Figure 8.45 that the pattern of vertical zonation was basically the same as in the earlier series of February 6th-7th (Fig. 8.44). Although densities of A. minutus were low (Fig. 8.45a), there was an obvious tendency for the distributions of small Alestes spp. and those of E. stellae together with prawns to be mutually exclusive.

A striking feature of E. stellae, M. niloticum and C. nilotica was the segregation of size groups by depth. In E. stellae (Fig. 8.45a) adult fish of 2-3 cm FL occurred exclusively at depths greater than 20 metres, below the midwater scattering layer. At station 1 in the centre of the lake, densities of adult E. stellae increased downwards from the scattering layer to reach a maximum at depths greater than 70 m. Results from stations 6, 4 and 1 (Fig. 8.45a) indicate that densities of adult E. stellae tended to increase from west to east in the deeper part of the transect. At station 4 near the east coast, at a depth of 60 metres, relatively high concentrations of these fish occurred throughout the water column below the scattering layer. Smaller size groups of E. stellae were chiefly confined to the upper zone above the scattering layer and were most abundant at station 1 in mid-lake. A minor proportion of 1-2 cm fish extended into the deeper waters of the lake, but fish of less than 1 cm FL were noted below the scattering layer only in the 20-30 cm zone where numbers were very low (Fig. 8.45a).

The vertical distribution of Macrobrachium niloticum (Fig. 8.45b) was similar to E. stellae with the larger stage IV and V prawns virtually restricted to deeper water below the scattering layer. Stage

I-III M. niloticum were concentrated in the surface layers, and although moderate densities were noted below the scattering layer in the 20-30 m zone, only occasional individuals penetrated further.

The Caridina nilotica population consisted principally of immature stage I-III prawns and was virtually confined to the upper layers (Fig. 8.45c). In this species, the highest densities were noted inshore, whereas in M. niloticum most stage I-III individuals occurred in mid-lake.

Densities of Lates spp. post-larvae (Fig. 8.45a) were generally low, but with the exception of station 8 near the west shore, these fish were recorded at all stations, occurring in the more superficial layers of the lake down to a maximum depth of 30 m.

The vertical distribution of small pelagic fish and prawns in townet samples is compared in Figure 8.46 with echo integrals recorded simulataneously during the transect. All species, with the exception of Alestes minutus, are included in the townet data in which densities are quoted in mg/100 m^3. Echo integrals are expressed as integral per unit volume and are thus comparable with the townet data. For technical reasons it was impossible to obtain reliable integral readings at short range, and as a result no data are available for the top 10 or 15 metres.

Figure 8.46 shows that at each station maximum echo integrals were recorded at depths of between 10 and 20 m, which coincided with the position of the midwater scattering layer. Strikingly low catches per effort in this depth zone (Fig. 8.46) indicate that the contribution made to echo integrals in the midwater scattering layer by Engraulicypris stellae and prawns was negligible. Since catches of Alestes minutus, the chief constituent of the scattering layer, were low in relation to other species (Fig. 8.45a) the highest echo integrals might have been expected to occur in depth zones away from the layer. The probable explanations is that at routine threshold settings Engraulicypris stellae and prawns were too small for their echoes to be discriminated from noise, and as a result they were lost during the processing of the integrated signals; Alestes minutus exceeded the critical size. Results from oblique metre townet surveys confirm that in deeper areas of open water, E. stellae formed a high proportion of the total biomass of all fish.

DIEL CHANGES IN THE VERTICAL ZONATION OF SMALLER PELAGIC SPECIES

Diel changes in vertical distribution were investigated with the opening/closing metre townet on 7th November 1975. The study was based on two series of samples, the first made during the afternoon between 14.40 and 17.15 hrs EAT, and the second after dark from 19.20 to 21.16 hrs. The sampling locality was situated ca 2.5 km east of Longech Spit, with a lake depth of 30 m. Each series consisted of 7 tows made at the following depths:

0 - 1 m
1 - 5 m
5 - 10 m
10 - 15 m
15 - 20 m
20 - 29 m
29 - 30 m

By day, the scattering layer was situated in the 5-10 m depth zone.

Results are illustrated in Figure 8.47 where catch per effort is expressed as numbers per 100 m^2 for each depth zone. The general pattern of distribution in the afternoon series was similar to that observed in the lake transect. As during the transect, densities of E. stellae, M. niloticum and C. nilotica were much reduced in the vicinity of the midwater scattering layer where peak numbers of A. minutus were recorded. However, no marked size variation was noted in E. stellae with depth and most fish ranged from 1-2 cm FL above and below the scattering layer.

The samples collected after dark showed that noticeable changes in distribution had occurred with E. stellae, Lates post-larvae and the two species of prawns all tending to move downwards in the water column but with A. minutus shifting slightly upwards (Fig. 8.47). In E. stellae the daytime pattern of bimodal distribution had changed to a unimodal pattern with peak numbers occurring in the 10-15 m depth zone. Relatively high numbers of small M. niloticum remained in the 1-5 m depth zone after dark but larger prawns concentrated between 20 and 29 m. This concentration was clearly visible on echo-records as a broad diffuse 'smoky' trace at depths ranging from 20 to 24 m.

A comparable series of day and night samples was made in the same locality, east of Longech on 7th July 1975 when lake transparency was close to the seasonal peak. As a consequence the pattern of vertical zonation was different to that observed in November 1975 and the pelagic forms tended to occur at greater depths. The scattering layer was situated at a depth of 15-23 m and the surface zone was thus relatively extensive. Immature E. stellae and prawns formed a high proportion of the total catch and A. minutus was recorded only at 20-25 m in the lower part of the scattering layer. At night, concentrations of E. stellae had shifted downwards to reach a peak in the 10-15 m zone. Prawns also moved downwards but tended to be more evenly distributed though the water column. As in other studies of diel behaviour patterns (Figs. 8.35 and 8.47) A. minutus underwent a definite migration towards the surface.

THE HORIZONTAL DISTRIBUTION OF OPEN WATER FORMS

Distribution charts for most of the species occurring in the oblique metre townet samples (see Table 8.21) appear in Figures 8.49-60. Results from three seasonal periods, June-July, August-September, and November-May are presented separately. Catches for each species at each station are expressed as number per standard haul. These observations are discussed briefly in the present section, but the results for most of the species are considered at length in the detailed biological accounts (see Chapters 4, 9, 10 and 11).

The pattern of spatial and seasonal distribution in small open water fish and prawns caught in metre townet samples varied considerably from species to species. Three main categories are recognisable:

(a) Species with a lakewide distribution present throughout the year:

Alestes minutus

A. ferox

Barbus turkanae

Engraulicypris stellae

Lates spp. post-larvae

Haplochromis macconneli

Macrobrachium niloticum

Caridina nilotica

Of these, B. turkanae and H. macconneli are strictly demersal in distribution and were probably caught in oblique townet hauls as the net approached the bottom.

Distributions of E. stellae and the two prawns M. niloticum and C. nilotica were basically similar to one another with relatively minor differences in abundance between the northern and southern parts of the lake, although considerable local variation was apparent. The similarities in the distribution of the two species at the northern end of the lake during the peak flood season August-October is particularly striking (Figs. 8.54, 8.59 and 8.60); in each case, densities declined sharply in the vicinity of the Omo Delta, presumably as the result of lowered salinities prevalent in the area (Fig. 1.68c).

The survey indicates that Alestes minutus concentrated chiefly at the northern end of the lake (Fig. 8.51). High densities were also noted at stations near the west shore in the Central Sector. This area was not effectively covered by sampling with oblique townet hauls, and as a consequence populations of A. minutus in the sector may have been underestimated. Densities of A. minutus became progressively lower further south.

Lates post-larvae were present at a high proportion of stations throughout the year. Numbers were generally greatest at the northern end of the lake and peak catches (Fig. 8.58c) were recorded during November 1972. It was not possible to distinguish between the post-larvae of the two species of Lates, and their relative importance in the catches is unknown.

(b) Species chiefly confined to the northern sector of the lake, occurring both as adults and post-larvae, and present throughout the year:

Micralestes acutidens

Chelaethiops bibae

Both the above species were also commonly recorded in shore samples from the northern basin and extended down the west shore as far as Ferguson's Gulf. In metre townet catches M. acutidens (Fig. 8.52) was also recorded rarely from the vicinity of Ferguson's Gulf and Central Island but the two species were mainly restricted to the extreme north of the survey area. Data for November-May (Fig. 8.52) suggest a south eastern shift in the offshore distribution of the two species towards Koobi Fora Spit. This is probably correlated with a southward movement of turbid water down the east coast of the northern sector which occurs each year at the end of the flood season, with the renewal of normal lake circulation (see Chapter 1, Fig. 1.68d).

(c) Species occurring seasonally as larvae or post-larvae, chiefly confined to the Northern Sector of the lake:

Hydrocynus forskalii
Alestes baremose
Labeo horie
Synodontis schall

Post-larvae of all the above species occurred regularly in metre townet catches. They were confined chiefly to the flood season and tended to concentrate in the northern part of the Northern Sector (Figs. 8.49, 8.50, 8.53 and 8.56) suggesting that the most important spawning grounds were situated in the vicinity of the Omo Delta. Isolated examples of the four species, particularly L. horie and S. schall were, however, caught from time to time in the Central Sector as far south as the Ferguson's Gulf area.

The post-larvae of other larger commercial species of fish were not observed in the open waters of the lake, but early immature Bagrus bayad and Schilbe uranoscopus of 3-4 cm FL were caught in a small proportion of metre townet samples near the Omo Delta (Fig. 8.57) and Chrysichthys auratus of 2-3 cm FL occurred at two stations on the east shore opposite the Kerio Delta.

Values of catch per effort for all oblique metre townet hauls have been converted into areal densities (gm/100 m^2). Data for the various species were then sorted on the basis of lake sector and grouped according to depth. The results for the three sectors formed by grid rows A-G, H-R, and S-Y (see Fig. 8.1) are presented in Figure 8.61 where the histogram bars are proportional to the mean biomass per unit area.

The highest mean value was noted in the Northern Sector where, in the 10-20 metre depth zone, a density of 864 gm/100 m^2 was calculated for Alestes minutus. To the south, densities of A. minutus fell progressively and the lake depth at which maximum catches for a particular sector were recorded, increased.

Engraulicypris stellae was the dominant form in metre townet catches in the Central Sector. Relatively high values of catch per unit area were recorded at nearly all depths with the exception of the 10-20 m zone. The irregular pattern of depth distribution may be of significance, since it was repeated at lower densities and in slightly deeper water in the Southern Sector (Fig. 8.61).

Catches of Macrobrachium niloticum varied from sector to sector in proportions similar to those observed in E. stellae but Caridina nilotica shows a greater tendency to concentrate in the Central Sector.

The contribution made by other species to biomass in metre townet samples was small. Comparatively high values were recorded for Micralestes acutidens in the Northern Sector, and Barbus turkanae together with Haplochromis macconneli both made a significant contribution to total catch in the deepest parts of the Southern Sector.

ESTIMATES OF TOTAL BIOMASS FOR SPECIES OCCURRING IN METRE TOWNET CATCHES

Total biomass by depth zone and sector has been estimated for species caught in the metre townets (Table 8.22). These results show that out of a lakewide total of 34,300 tonnes, *Engraulicypris stellae* and *Alestes minutus* each contributed over 10,000 tonnes, and prawns nearly 5,000 tonnes. The estimates also illustrate the relative poverty of the Southern Sector of the lake in terms of biomass compared with other areas.

SUMMARY

Metre townets were used to determine the vertical zonation and the lakewide distribution of smaller pelagic species of fishes and prawns.

Engraulicypris stellae, *Alestes minutus*, *Lates* post-larvae and the two prawns *Macrobrachium niloticum* and *Caridina nilotica* were the principal species involved. Vertical zonation was well-defined with *E. stellae* and the two prawns showing marked changes in depth distribution according to size, with the larger individuals occurring in deep water below the midwater scattering layer. The three forms avoided the scattering layer where *A. minutus* predominated.

Diel cycles of vertical migration were demonstrated for all species concerned.

Patterns of lakewide distribution were shown by a series of oblique metre townet hauls. Species diversity and biomass were highest in the Northern Sector of the lake and lowest in the Southern Basin. During the flood season catches in the Northern Sector included large numbers of post-larvae of larger fish including *Hydrocynus forskalii*, *Alestes baremose*, *Labeo horie* and *Synodontis schall*.

GILLNET SURVEY

A J Hopson and A A Q R McLeod

INTRODUCTION

METHODS

RESULTS

Sampling stations

Bottom set gillnets

Surface gillnets

Midwater gillnets

SUMMARY

INTRODUCTION

An extensive programme of gillnetting was carried out on commercial fishing grounds to provide estimates of both catch per effort and species composition in the Turkana fishery. The results have been reported in Chapter 6 (page 372).

Gillnets were also used to provide additional information on the distribution of open water fish, particularly surface forms such as Hydrocynus forskalii and Alestes baremose. It is these investigations which are summarised in the present section. Much of the data has been derived from overnight settings carried out during 1974 and 1975 in the course of routine cruises with R V HALCYON. The nets were usually deployed in the vicinity of the nightly anchorages and for this reason most records are from localities on the comparatively sheltered east shore of the lake. Gillnets were also set regularly from smaller boats in the vicinity of Longech Spit.

A major drawback to the interpretation of gillnet data is the difficulty of relating values of catch per effort to absolute stock densities. The results, however, provide a valuable index of relative abundance.

METHODS

Multifilament nets, usually white in colour, mounted with 50% slack and 46 m in length were used during the present investigations. The nets were of three types:-

(a) Bottom set nets ranging in stretched mesh size from 2 inches to 10 inches in increments of 1 inch and mounted to fish approximately 4 m deep. Twine size ranged from 210/6 in 2 and 3 inch nets, to 210/21 in 8-10 inch nets (see Chapter 6, Table 6.31). The nets were weighted to sink with patent lead line.

(b) Surface set nets ranging from 2 inches to 4 inches in ½ inch increments, and 5 inches to 8 inches in 1 inch increments. Twine size varied from 210/12 in 2-4 inch nets, and 210/15 in 5-6 inch nets to 210/18 in 7-8 inch nets. It was later found that the 3 inch net had a stretched mesh size of 2⅞ inches due to an error in manufacture. The nets were mounted to fish approximately 3.5 m deep, with a footline of 17 mm diam. sisal rope. The sisal was sufficiently heavy to sink the bottom of the net without the addition of extra weights.

(c) Midwater nets of green nylon, with a stretched mesh size of 4.3 inches and with a mounted depth of 5.5 m. The midwater nets were weighted to sink and were suspended from a series of surface floats by buoy ropes.

Fleets of gillnets were set before dusk, anchored at one end. A large dhan attached to the free end of the fleet helped to keep the nets along the line of the wind and prevented tangling. The gear was usually recovered in the early morning after dawn. Catch per effort has been expressed as kg/100 m headrope/night.

RESULTS

SAMPLING STATIONS

Information relating to sampling stations where surface or bottom set gillnets were fished during the present survey appears together with the results in Tables 8.24-26. Midwater gillnetting which was carried out during August and September 1974 was restricted to the open lake in the vicinity of Longech Spit.

BOTTOM SET GILLNETS

The most comprehensive data are for the Longech Spit area where bottom set gillnets were fished on a transect running from shallow into deeper water during February-June 1974. The principal objective was to examine the distribution of fish in the bottom 4 metres in relation to the midwater scattering layer, situated during the study period at a depth of 13-19 m. Sampling stations were established as follows:

Station	Lake depth (m)	Position relative to scattering layer
A	9	Above
B	14	Upper fringe
C	18	Within
D	25	Below

Fleets of gillnets of graded mesh size from 2 inches to 10 inches in 1 inch increments were fished at each station in turn. The results are presented in Table 8.24 and summarised in Figure 8.62 where data from all mesh sizes have been combined for each station. The variations of catch per effort with mesh size which are apparent in all species (Table 8.24) were due to the effects of mesh selectivity, a topic which is discussed at length in Chapter 6. Marked trends in the depth distributions of various fish are clearly seen in Figure 8.62.

Several species occurred most abundantly inshore and became less common or absent in deeper waters. Of these, Citharinus citharus was the most restricted in distribution (Fig. 8.62) but Distichodus niloticus and Labeo horie also declined sharply with depth and were caught plentifully only on or above the upper limits of the scattering layer. These are demersal fish and the scattering layer marks the offshore limits of their normal range. A similar pattern of distribution is indicated by results for Hydrocynus forskalii and Alestes baremose which are, however, pelagic species extending throughout the open waters of the lake on the surface and thus avoiding the deeper gillnets. Barbus bynni occurred regularly at all stations but numbers tended to increase in the scattering layer. Maximum catches of Synodontis schall and Lates longispinis were noted at station C within the scattering layer, but the proportions of these fish were also high in the deepest nets. Bagrus bayad also occurred principally in offshore catches.

The present findings agree closely with the results of the bottom trawl survey detailed above.

SURFACE GILLNETS

The species composition of the surface gillnets varied considerably with mesh size. The main surface species Hydrocynus forskalii and Alestes baremose were caught principally in fine gillnets of 2-4 inch stretched mesh. Results for the fine nets have been treated separately from data for the coarser nets of 5-8 inch mesh.

Records for a total of 18 fine mesh gillnet stations are tabulated in Table 8.25 a-r. The information for 2½ - 3½ inch nets is summarised in Figure 8.63 where mean catch per effort for the three mesh sizes has been combined. The catch rate shows a marked tendency to decrease along the lake from high values in the extreme north to more moderate levels in the south. Alestes baremose was clearly the most important fish, particularly in the northern sector where the species concentrates in the flood season prior to spawning. Hydrocynus forskalii was usually the subdominant species.

Sampling sites were mostly situated in coastal areas, but the high proportion of A. baremose in the limited catches from mid-lake and from comparatively deep water near the main islands suggests:

(a) that the species extends commonly throughout the open waters of the lake

(b) that the abundance of this species has been considerably underestimated in the midwater and frame trawl surveys where H. forskalii always greatly outnumbered A. baremose

Mean values of catch per effort for the combined 2½-3½ inch fleet from all stations have been averaged to give the following overall means :

Alestes baremose	26.3 kg/100 m/night
Hydrocynus forskalii	12.0 kg/100 m/night

The distribution of Synodontis schall was erratic in fine gillnet catches and although the overall proportion was moderately low, large concentrations were sometimes encountered (Fig. 8.63). Apart from Labeo horie which dominated catches in the somewhat specialised environment of Ferguson's Gulf, other species formed only a minor proportion of the catch (Table 8.25k). Alestes dentex was markedly local in distribution, occurring chiefly on the east shore from Allia Bay southwards.

Surface set gillnets of 5, 6, 7 and 8 inch mesh were set at a total of 7 stations, all situated on the east coast of the lake, during the present investigations. The data have been analysed in Table 8.26 a-h where supplementary information on 6" gillnets at five stations in the Loiengalani area is also given. Due to the smaller number of replicates and the relatively low numbers of large fish involved, the results are less consistent than was the case in fine mesh nets. In consequence it is difficult to identify distributional trends. Lates niloticus tended to dominate catches at stations throughout the survey area. Labeo horie and Barbus bynni were widespread subsidiary species, at times ranking high in importance. Notably high catches of Citharinus citharus were recorded at Ilaret in the Northern Sector. This species was otherwise thinly distributed throughout the east coast survey area, occurring at 6 out of the 12 stations. The presence of Bagrus docmac at 5 out of 6 stations in the Loiengalani region is also notable. The species was rare in bottom trawl catches but displayed a definite preference for hard substrates. The present results suggest that B. docmac is comparatively numerous on rocky coasts in the southern basin.

MIDWATER GILLNETS

Trials with midwater gillnets of 4.3 inches stretched mesh were carried out in the open lake off Longech Spit during August and September 1974. The objectives were (a) to study the vertical zonation of fish and (b) to investigate the possibility of catching midwater fish, particularly Lates longispinis, commercially with this type of gear. Five sampling stations were established on a transect running east from Longech Spit:

Station	Distance offshore (km)	Lake depth (m)	Depth zones sampled
A	0.8	10	2
B	1.0	16	3
C	1.7	22	4
D	3.0	27	5
E	7.0	50	8

At each station gillnets were set at various levels within the water column, the number of depth zone samples increasing with lake depth. During the study period the midwater scattering layer was situated by day at a depth of 10 to 20 metres. It seems likely, however, that the majority of fish were caught in the gillnets at night.

The results presented in Table 8.23 show a basically similar pattern of fish distribution to those of other surveys carried out in the area, particularly the diel series of frame trawl tows (Fig. 8.35). The relative proportions of various species, however, differed. *Synodontis schall* dominated catches at all stations, extending vertically throughout the entire water column but tending to concentrate on the surface. In the case of *Lates longispinis*, catches were generally much smaller. This species also ranged widely in depth but peak numbers usually occurred on the bottom or in the midwater layers. As usual in the present series of surveys *Bagrus bayad* was chiefly restricted to deeper water offshore, but a single individual was caught in the surface net at station D, showing that the range of vertical migrations of this species was at times considerable.

With the exception of *S. schall*, catches were generally too low for midwater gillnetting in the sampling area to be commercially viable. Further trials should be carried out in other areas near the west coast of the lake to the north of Longech where *Lates longispinis* is known to concentrate.

SUMMARY

Three series of investigations involving gillnets are described.

A graded fleet of bottom-set nets was fished in the Longech area during 1974 to demonstrate the distribution of demersal fish in relation to the midwater scattering layer. The results from four stations varying in depth showed that *Citharinus citharus*, *Distichodus niloticus* and *Labeo horie* were most plentiful in shallow water whereas *Bagrus bayad* predominated at the deepest station below the scattering layer. *Synodontis schall* and *Lates longispinis* reached maximum abundance within the scattering layer.

Surface gillnets of 2½-3½ inch stretched mesh, set chiefly in coastal waters at stations throughout the lake proved that *Alestes baremose* and *Hydrocynus forskalii* were common, and the former at times abundant, in the Northern Sector. *Lates niloticus* was the principal species caught in surface gillnets of 5-8 inch stretched mesh.

With the exception of *Synodontis schall*, catches were generally low in a series of midwater gillnets set at various stations in the Longech area during August and September 1974.

ACOUSTIC SURVEYS

M G Pawson

INTRODUCTION

METHODS

THE ACOUSTIC EQUIPMENT

SURVEY PROCEDURES

CALIBRATION

RESULTS AND DISCUSSION

- The role and limitations of acoustic survey methods
- Species distribution in the demersal population
- Standing stock esimates

SUMMARY

INTRODUCTION

A major objective of the Lake Turkana Fisheries Research Project was to estimate the abundance of commercially important fish species and to determine their lakewide distribution throughout the year. The market sampling programme described in Chapter 6 provided data on the stocks of fish taken in the commercial fishery, which in 1974 extended offshore to a maximum depth of 15 m, and was located from Loelia northwards on the west shore, and between Porr and Allia Bay on the east shore. The remaining areas were sampled by shore survey (see Chapter 7, pages 559 and 565), or from R V HALCYON using bottom and midwater trawls and gill nets (this Chapter). In addition it was decided to obtain information on fish abundance and distribution by acoustic methods, which enabled a rapid survey of the whole lake (in water deeper than 10 m) to be made 3 or 4 times in a year. Staff from the MAFF Fisheries Laboratory, Lowestoft aided the ODM team to design and carry out the acoustic surveys.

This section describes the methods used on the acoustic surveys, discusses the results from a fisheries assessment viewpoint, and outlines the problems encountered in adapting acoustic techniques to the particular environmental and biological features of Lake Turkana.

METHODS

Prior to the present investigation the fish populations of Lake Turkana have only briefly been examined acoustically by CUSHING in 1971 (pers. comm.) and incidentally by others during topographical investigations of the lake bed (HOLNESS, 1969). Consequently the design of the acoustic equipment was based on rather limited information regarding the target types and operating conditions likely to be encountered.

The original gear supplied to Lake Turkana in December 1973 was considerably modified prior to and during the survey period, from June 1974 to July 1975. A technical report by NOCKELS (1976) fully describes these modifications and they will not be discussed in detail here.

THE ACOUSTIC EQUIPMENT

The basic acoustic equipment system used on R V HALCYON during these surveys is shown in Figure 8.64, and consisted of a Triton type 44 fish echo counting system, coupled to a Simrad QM Mk II integrator unit with a Hewlett Packard 2 channel recorder, type 7702B. The system comprised two sections, the echo sounder unit and the signal processing unit. The former included either a Kelvin Hughes MS21 or an Alden 319DA moist paper recorder which, whilst providing visual records of targets along the ship's path, also generated the timing pulses to activate the transmitter, 4/s and 4-22/s, respectively. The transmitter triggered a resetable transmission counter, and transmitted a 100 μs electrical pulse, with a peak output power of 1 kW at a frequenty of 100 kHz, to a 7.5 cm ceramic disc transducer with a beam angle of 12 degrees. The acoustic pulse had a length of 15 cm and a source level of 115.7 dB ref. 1 μbar at 1 m.

Echoes were received via the transducer, which had a voltage response of -82 dB ref IV per bar, and then amplified in three stages (Fig. 8.65). First the signals were subject to a fixed gain to ensure that they passed to the time varied gain (TVG) amplifier within the correct dynamic range. The TVG amplifier generated a gain which was automatically increased with time, and therefore, range, with the result that a given target had the same signal amplitude at any range up to 100 m. Finally the signals were frequency filtered and amplified to a level compatible with the signal processing equipment's requirements.

The receiving system had a number of secondary functions which were particularly important when the gear was used for survey work. The sampling range and interval generator produced a pulse for each transmission which commenced after a delay corresponding to the selected "depth", and terminated after the range "interval" chosen to be sampled in the water column. This pulse was passed to the signal processing unit and also caused the sampled interval to be marked on the moist paper record.

The lake bottom signal was assumed to be greater in amplitude than fish signals, and whenever echoes occurred above a preset threshold, the "bottom-stop" comparator generated a short pulse. This terminated the sampling gate if required. The threshold could be varied to suit the survey conditions, since rough weather or uneven substrate and depth can change the character of the lake bed echo. Echoes from particularly dense fish aggregations near the surface at times triggered this system at the normal survey threshold level, and an inhibit circuit was incorporated to prevent the generation of a bottom-stop pulse for a variable time after transmission. In this way false triggering was avoided whilst using the most sensitive bottom-stop thresholds.

The bottom-stop pulse was used to control a "white line" switching circuit which, by briefly suppressing the bottom echo mark on the

the paper record, enabled fish echoes close to the bottom to be more easily recognised. The suppression could be delayed (e.g. in shallow water) to ensure that the lake bottom echo was visible before the white line took effect.

The sampled interval could also be initiated relative to the lake bottom, in the "bottom following" mode. Here the range gate was opened at a chosen distance from the lake bed, and terminated by the bottom-stop pulse. There was also provision for terminating a midwater sampling gate at the start of the bottom follower gate. The receiver unit generated a series of pulses which were used to mark the paper record at 1 and 10 m intervals as required.

An estimate of the total biomass within sampling gates was obtained with the Simrad integrator and fed to the Hewlett-Packard chart recorder. This equipment is in standard use for fish abundance estimation and records the total returned acoustic energy from each transmission, or for a given survey distance, in analogue form (DRAGESUND and OLSEN, 1965). An amplitude threshold can be set to exclude "noise", and only target signals above the threshold are integrated. The integrator contained its own amplifier and sampling range gate control and markers, the latter being linked to the receiver and moist paper recorder. The basic Simrad package was modified to be compatible with the other equipment and to allow more flexibility in survey technique. The bottom-follower unit had its origin in this apparatus and could be used with both moist paper recorders. The ship's log output was coupled to the integrator to enable automatic compensation for survey speed, such that recorded integrals were proportional to target density per unit distance steamed, and not per transmission.

The signal processing equipment also contained a signal discriminator, shoal and single target counter units, and a special display facility, which although not used to provide data for this report, were run as necessary to obtain additional information on fish distribution and abundance. The discriminator unit counted the number of cycles in a returned echo at a pre-set amplitude (PEARSON and MITSON, 1973). Since the signals were not rectangular pulses on output from the receiver, the number of cyles counted was dependent on the selected threshold (Fig. 8.66) as well as the echo's amplitude and duration. It was assumed, however, that echoes from single, resolvable, fish targets would produce a lower cycle count than multiple target echoes (i.e. fish in the volume insonified in one transmission lying within less than half a pulse length, 7.5 cm, of each other in range from the transducer), and a cycle number could be found below which echoes were attributed to "single" fish. The discriminator separated "single" from "shoal" echoes on this basis, and passed them onto the counter units which respectively summed singles cycles or shoal counts.

The special display unit was designed to improve the information content of the moist paper records in respect of fish echoes. Signals from the discriminator were fed to the paper recorder only if they exceeded an amplitude threshold, which could be varied to indicate the targets' size. The resultant signals were not the received pulses, but were regenerated with a longer duration and constant amplitude, and were therefore better defined. This facility proved most useful for calibration work.

A manual/automatic programme enabled the entire acoustic survey system to be controlled by stop and start buttons. In the automatic mode the signal processing and recording equipment reset at 2 km intervals whilst the manual mode allowed the size of sample units to be chosen by the operator. Although the counting information was lost unless reset by hand, the echo sounder and integrator paper records were automatically marked, and the transmission counter and integrator units reset, after each survey unit.

The Kelvin Hughes MS21 paper recorder was normally used to provide a visual record of each survey, despite a displayed range limitation of 30 m. The whole water column was depicted on the paper recorder of the ship's navigational Kelvin Hughes MS44 (48 kHz) echo sounder, which had its power output reduced to avoid interference with the acoustic survey equipment. The Alden high speed recorder had a variable writing, and hence, transmission rate, and was used to obtain more detailed visual records of target populations. In order to obviate the problem of superimposition of bottom echoes from one transmission onto the sampled range gate of succeeding ones, a unit which reduced the transmission rate by a factor of 2 or 4 and inhibited the appropriate writing gate, with the same writing rate, was fitted to the Alden recorder Consequently the range displayed remained constant, but gating was possible from the surface down to 100 m.

The operations of the transmitter and receiver were monitored via a performance checking unit (PCU), which could be used to observe either the pulse transmitted from signals received at the transducer, or the transmitter output, and to trigger an oscilloscope or inject signals into the system from a generator unit. The signal generator provided 100 kHz pulses of differing amplitude and duration at a chosen range, and could be triggered by the transmission pulse. The oscilloscope is an important part of any acoustic survey, and together with a Polaroid camera it was used to record waveforms throughout the system from generated signals and natural or standard target echoes, and to measure gains, transfer charactertistics, etc.

SURVEY PROCEDURES

Navigation on Lake Turkana was safe only in daylight and, because vertical fish distribution appeared to change at dawn and dusk, acoustic surveys were limited to a maximum of 12 hrs per day. This period was normally reduced in view of the strong winds encountered each morning. With anchorages restricted to the east side of the lake, South Island and Ferguson's Gulf (Fig. 8.67), each day's cruise track was often restricted to a return crossing of the lake at the survey speed of 6 knots. The survey grids shown in Figure 8.68 were therefore determined by environmental rather than biological or statistical considerations. Position fixing is described on page 626.

A preliminary survey in June 1974 indicated that the vertical fish distribution during daylight over most of the lake could be assigned to three "populations" from acoustic and sampling viewpoints. These were:

(1) Fish accessible to a bottom trawl within 4 m (the assumed headline height) of the lake bed, i.e. Labeo horie, Barbus bynni, Schilbe uranoscopus, Bagrus spp., Chrysichthys auratus, Synodontis

schall, Lates spp. and Haplochromis spp. "Minority" species (see page 589) were not included in the present analysis.

(2) The midwater layer of small fish vulnerable to the midwater trawls or tow nets i.e. Alestes minutus and A. ferox.

(3) Larger fish occupying the water column above region 1, i.e. Hydrocynus forskalii, Synodontis schall, Lates spp. and Sarotherodon spp.

Although there was evidence that most species common to populations 1 and 3 were probably more abundant in 3 (see pages 599,601) they were certainly more accessible to a commercial bottom trawl fishery in water deeper than 10 m. The remaining species in 3 almost always occurred at a depth of less than 15 m. Consequently the two channels of the integrator were set to sample range gates encompassing populations 2, the "midwater scattering layer" (manual setting), and 1, the "demersal population" (bottom follower with 4 m gate), (Fig. 8.69). The counting system was set to sample signals from between these gates. During surveys integrals and counts were recorded for sample units of 2000 transmissions. Samples of the target populations were taken when possible by trawl, though the restriction on survey time reduced this to an average of two hauls per day. A routine calibration and integrator and counter test was carried out daily before surveying, by injecting a standard simulated pulse and noting the output of the equipment at standard gain and threshold settings. Noise levels were also measured with and without the transmitter firing, in order to select a survey speed at which noise levels produced negligible integrals.

CALIBRATION

Theoretically it is possible to quantify acoustic data in terms of fish biomass if the system parameters, i.e. source level and voltage response of the transducer and the gains throughout the system, are known and if a target strength value is available for the population being sampled. Measurements of source level and voltage response were obtained by suspending a calibrated hydrophone or standard target on nylon monofilament, approximately 20 m beneath R V HALCYON's hull-mounted transducer. The hydrophone and standard (or fish) target were centralised in the beam by tilting R V HALCYON with ballast until a maximum signal was monitored on the oscilloscope via the PCU. The gains were measured as described above. A major difficulty, however, was encountered in measuring the target strength of various species of fish, and in applying such values to the data.

The target strength of an object is defined as the ratio of reflected energy to incident energy, measured 1 m from the target, and can most easily be measured by placing the target on the "axis" of the transducer beam. As acoustic targets fish pose many problems, not least of which is the variability in a single species target strength due to fish size, aspect, attitude, behaviour and physiology (WELSBY, 1975). Consequently very few reliable values have been given for even the most thoroughly investigated species, especially since the in situ behaviour and physiology of target species is very difficult to determine (FAO, 1978). Although an indication of the target strengths of some species of fish were obtained at Lake Turkana, by substituting live and dead specimens for the standard targets used in the calibration procedures outlined above, the diversity of morphology and size of the normally mixed populations in the lake ruled out any meaningful attempt to quantify the acoustic data in this way.

It was decided instead to try to correlate echo integrals and bottom trawl catches in order to estimate the abundance of the demersal population. Since trawl catch rates are likely to be more variable than integrated echo levels of the same fish population, it seemed justifiable to take a mean of catch rates associated with a narrow range of echo integrals, and to plot this against the mean of integrals in that range. Data obtained in this way for the whole range of integrals was used in a weighted linear regression analysis. The difficulty encountered in quantitatively sampling the midwater scattering layer reported on page 633 meant that only a relative density distribution of the total population could be produced, which should be compared with the findings of fishing samples reported on page 609.

It rapidly became apparent that the accuracy of the counting equipment depended on the shape of the transmitted pulse and hence the received echo, in addition to the discrimination cycle threshold, the amplitude threshold and the size of the signals being counted. In effect this resulted in a large bias towards shoal counts (see Fig. 8.70) and it was decided not to use this system for biomass estimation until further information was available on the magnitude of the errors involved.

Estimates of the relative density of targets in a range gate were obtained by applying the following formulae:

$$D = I\ [S\ R^2\pi\ (\tan\ \Theta)^2]^{-1} \qquad \ldots(1)$$

or

$$D = 12I\ [S\ (R^3-(R-4)^3)\pi\ (\tan\ \Theta)^2]^{-1} \qquad \ldots(2)$$

where I = Integral/2000 transmissions in mm (corrected as necessary)

S = Distance steamed during 2000 transmissions in km

Θ = angle of transducer beam in degrees (6.84°)

R = Range to scattering layer (1) or lake bed (2) in m

D = Relative density of targets in mm/km/m^2

For the midwater scattering layer R was estimated in each sampling unit and it normally changed little from unit to unit. For the demersal population R was taken to be the mean of the bottom depth at the start and finish of each unit, and fish were assumed to be uniformly dispersed through the 4 m gate. By multiplying the density per unit volume by 4 (included in equation 2) a density per unit area, directly comparable to the midwater layer's density, was obtained. The densities were then plotted onto charts of the cruise track and contoured. Estimates of total relative abundance were made by raising the area occupied by each contour interval by its mean (calculated) density, and then summing these values.

Absolute biomass was calculated for the demersal population from the catch/integral regression

$$C = 47.36\ D + 12.22 \qquad \ldots(3)$$

where C is catch in kg/km of towing

D is from equation 2

Since it was estimated that the bottom trawl had a wing to wing opening of 10 m, and that its catching efficiency was assumed to be 100% between the wings, the effective area swept during 1 km was 10^{-2} km^2. Consequently, fish abundance in A is given by

$$A = 10^{-1}.C \text{ tonnes/km}^2$$

An attempt was made to apportion the total biomass in the demersal population as follows:

The percentage composition of catches of demersal fish by species was calcualted for sampled statistical (10 x 10 km) squares in each of three periods, July-October, November-February and March-June, and was based on the data used to construct Figures 8.8 to 8.17. Pelagic species such as Hydrocynus forskalii and Alestes spp, which might have been caught during shooting and hauling the net, were not included in the analysis. These values were then raised by the mean integral of acoustic survey units in each square, giving an estimate of the relative biomass of each species in each square sampled. Values for unsampled squares were estimated by interpolation on the basis of acoustic density distributions in nearby squares.

RESULTS AND DISCUSSION

THE ROLE AND LIMITATIONS OF ACOUSTIC SURVEY METHODS

Although it is apparent that acoustic systems cannot yet be used to produce quantitative fish abundance estimates in a mixed species situation, due primarily to target strength and species identification problems, the techniques outlined in this section can be used to support and extend data from fishing surveys, both in time and space. In an environment such as Lake Turkana, where all water deeper than 10 m can be adequately surveyed in 10 to 20 days depending on weather conditions, the relative density distribution of total fish populations in pre-determined sampling strata can be satisfactorily obtained. Species identification by fishing is, of course, a necessity, but the advantage of rapid coverage allowed by acoustic techniques is lost if too much time is taken in fishing. At Lake Turkana, in fact, it proved impractical to make more than 2 or 3 trawl hauls per day on acoustic surveys, since noise from both the ship's movement through the water and from the engine and propeller precluded speeds above 6 knots on survey legs (see page 628). Consequently information on species distribution and proportional representation in the target populations was best obtained from fishing surveys carried out at other times.

In the analysis of the distribution of the demersal fish population the trawl samples taken during the project were used only to determine species composition and distribution. The selectivity of the sampling gear for the species involved is largely unknown (see page 645), but from a practical fisheries viewpoint catch rates are more important than total population indices, in the first place. The ultimate objective, estimates of the standing stock of commercially important fish, could not be achieved by purely acoustic techniques, although approximate target strength/length relationships were obtained for Barbus bynni, Bagrus bayad, Synodontis schall and Lates niloticus, Figures 8.71 and 8.72. Further details of the methods and results of this work are given in NOCKELS (1976). These measurements were made at ranges greater than 7 m, since target strength measurements of standard targets at varying ranges indicated that consistent results approximating to theoretical values (-41.16 dB for a table tennis ball of diameter 3.5 cm, and -26.02 dB for a 20 cm diameter trawl float) could only be obtained at ranges beyond 7 m (Fig. 8.73).

The quantification of the relative biomass estimates depended, then, on the correlation between echo strength levels measured by the integrator, and catch rates during simultaneous trawling, and on the efficiency of the trawl in sampling the fish population. Figure 8.74 shows that there was a good relationship between integrals and catch rates if the expected variation in the latter is taken into account, although one point (.354, 54.08) was shown to be inconsistent with the model best fitted to the data. There appeared to be a good correlation between numbers of fish caught per hour and their weight, i.e. catch rates were not a function of mean fish size, which would bias the catch/integral relationship. The area swept by the bottom trawl and its efficiency are discussed on pages 586, and over most of the lake echo records indicated that the 4 m bottom following gate enveloped a large proportion of the fish below the midwater scattering layer, at least during daylight (Fig. 8.75).

SPECIES DISTRIBUTION IN THE DEMERSAL POPULATION

Figures 8.76 to 8.76i show the results of the analysis of species distribution in the demersal population for September and November 1974 and June 1975. These should be compared with Figures 8.8-8.17 which are based on trawl catches only. In most cases the two forms of distribution are in close agreement, as would be expected, with the reservation that the southern basin was rather poorly sampled by fishing, particularly during the July-October period. Hence extrapolations in this area are rather tenuous for most species, although in view of the distribution differences between November and June, it was decided not to use data from these periods in the September analysis.

The distribution of individual species will not be described in detail, but some comment on apparent anomalies seems appropriate, bearing in mind the restriction imposed on the acoustic survey by shallow water. These results concern the fish population occurring within 4 m of the lake bed, and the known greater vertical extent of such species as Schilbe uranoscopus, Synodontis schall and Lates longispinis suggests that for these species at least their abundance is underestimated in some parts of the lake (see page 599).

Barbus bynni: The presence of B. bynni in deep water south west of Porr in June has not been demonstrated.

Haplochromis macconneli: This species appears to favour deep water away from the shoreline and has not been taken at Koobi Fora, Eliye Point, The Hook, North Turkwell Point or at Sandy Bay at any time of the year.

Chrysichthys auratus: C. auratus was probably absent from the deep water between Central Island and North Island throughout the year.

Schilbe uranoscopus and Synodontis schall: No anomalies

Labeo horie: Labeo was not recorded from catches off Kataboi or between Moite-Eliye and Kerio-Sandy Bay in September, nor off Jarigole or North Turkwell in June.

Lates niloticus: Many trawl hauls contained only 1 or 2 individuals of this species which, on account of their size, could dominate the catch by weight. Consequently *L. niloticus* was probably less well sampled quantitatively by trawling than most other species and its absence from hauls is less significant. It appears, however, that water deeper than 10 m between Moite Point, Central Island and Oryx Point may have contained very few *L. niloticus* at any time during the surveys.

Bagrus bayad and *Lates longispinis*: It is unlikely that either of these species was absent from the statistical square east of Kerio in June.

STANDING STOCK ESTIMATES

The biomass estimates of the total demersal fish populations are given in Table 8.27, with a species breakdown in Table 8.28. Both methods of estimating standing stock from purely acoustic and acoustic plus trawl sampling data (see page 644) indicate that there was a lower population density below the 10 m contour in November, than in either September or June. This may be attributed to a combination of Omo floodwater attracting spawning fish into the shallow water at the north end of the lake, inundation of more littoral zone by the rise in lake level overall, or a general movement into shallower water, or off the bottom, due to the increase in turbidity in the northern part of the lake in November (see Fig. 8.77).

Discrepancies between the area surveyed in each cruise and the two estimates of total biomass for each period are functions of the analytical techniques used, and do not signficantly affect the accuracy of these results. During June 1975 the midwater layer occasionally occurred at such a depth as to enter the 4 m gate and merge with the "demersal population" as indicated in Figure 8.78. An allowance for this was made in the analysis of total biomass from acoustic survey data, which probably resulted in a small underestimate of the demersal population biomass. In the affected areas this is more accurately estimated by the statistical square method. Since the midwater scattering layer biomass was generally greater than that of the demersal population in areas in which the layer occurred, no correction was applied to its biomass, which will therefore be slightly overestimated. Investigations of the "smoky" traces observed mainly during the June 1975 cruise indicated that a proportion of the echo from the 4 m bottom gate was probably due to the presence of prawns (see page 644). A correction has been made for this in the analysis of the June 1975 data in Table 8.28 (by omitting sample units containing "smoky" traces from the calculation of mean echo density), and the areas involved are shown in Figure 8.76a. The occasional "smoky" trace observed during the cruises in September and November 1974 did not appear to cause any significant increase in echo levels.

It is felt that a relative density distribution of all targets in the midwater scattering layer is the limit of analysis which the data will support (Fig. 8.79). Very little is known about the lake-wide distribution of the species involved, *Alestes minutus* and *A. ferox*, or their relative abundance and vulnerability to sampling gears. In practice this population is only likely to be of interest to fisheries assessment as food for more commercially important species, or to a lesser extent as a source of fish meal. In this respect it is appropriate to give a tentative estimate of its biomass in relation to the demersal population, see Table 8.27. A source of error in these results is the degree of accuracy with which the depth of the scattering layer was measured. An error of 1 m around the mean lake-wide depth of 15 m would give a 25-30% difference in biomass.

The acoustic surveys indicated similar quantities for June 1974 and 1975, as might be expected, with a lower biomass in November. This apparent seasonal decrease in abundance may be due to the presence of turbid water at the north end of the lake resulting in the mid water scattering layer occurring above the depth range of the acoustic sampling gear (see Fig. 8.78), an inshore movement of the layer at this time or the annual post-spawning mortality of Alestes minutus and A. ferox (see Chapter 9, page 833). The former suggestion is supported by indications of the spread of Omo water in November both from conductivity measurements and direct observations of the extent of "brown water". Biomass estimates for each survey south of the November 10 m scattering layer depth contour are, in fact, quite similar.

CONCLUSIONS

During the period under review a great deal of acoustic data were collected, most of which are covered by this report. Some however, like the target strength measurements and cycle counts, were considered to be inadequately investigated or understood to be used in the population assessments, whilst others, such as the echo sounder and special display records, have also been used to support data from other aspects of the Project. The supporting function of acoustic survey techniques has been mentioned elsewhere (page 644), and until purely acoustic identification of species is achieved (by which time the in situ target strength problem will probably be solved), this role will be maintained.

The hydrographic environment of Lake Turkana, where acoustic absorption at 100 kHz is 0.2 dB/100 m compared to 2.8 dB/100 m in sea water, allowed a short, high frequency pulse to be used. This usually enabled fish targets to be resolved as single echoes, with the exception of the midwater scattering layer, which meant that individual fish could be counted from paper echo records, particularly when using the special display on the Alden recorder. It was shown that a good correlation existed between visual echo counts and integrals from the same target population, although counting at high target densities proved difficult. This also applied to the electronic counting technique, but at much lower densities, and it seems likely that the integration technique was justified in these circumstances. EHRENBERG (1972) discusses the magnitude and sources of acoustic fish abundance estimation errors.

The relative density distributions of both the midwater layer and the demersal population could only have been obtained using the methods described in this section, especially in view of HALCYON's deployment to a variety of tasks. They should provide a useful basis to enable any increase in exploitation at Lake Turkana to be efficiently directed. The standing stock estimates, however, must only be used to formulate management policies if they are supported by independent data on species abundance, population structure and realisable catch rates.

SUMMARY

Acoustic surveys of the fish populations of Lake Turkana in water deeper than 10 m were carried out between June 1974 and July 1975. A basic 100 kHz echo sounding system with time varied gain, feeding to a Simrad integrator and paper recorder, was modified to suit the environmental conditons of Lake Turkana and the characteristics of its fish population.

The distributions of a midwater layer comprising *Alestes minutus* and *A. ferox* and of the demersal population of fish accessible to a bottom trawl, were recorded three times in this period. Estimates of their abundance were made by quantifying the acoustic data with an echo integral/trawl catch correlation, and by assuming an efficiency for the bottom trawl. Standing stocks of the major species in the demersal population were estimated from their proportional representation in catches in each statistical square.

THE PHOTO-ENVIRONMENT AND PATTERNS OF MIGRATION AND DISTRIBUTION IN OPENWATER FISH

A J Hopson and A A Q R McLeod

The surveys considered above have provided detailed information on the distribution of openwater fish in Lake Turkana. The purpose of this discussion is to provide a synthesis of the various findings and it identify environmental factors controlling the diel and seasonal movements evident in many species.

Diel changes in vertical distribution are characteristic of numerous fish and crustacea in Lake Turkana. Typically, such behaviour involves an ascent towards the surface at dusk although several species exhibited reversed or modified patterns.

Many workers have investigated the problem of vertical migration in both marine and freshwater environments. Planktonic crustacea have been particularly well studied and one of the earlier investigations in this field was carried out on Lake Turkana by WORTHINGTON and RICARDO (1936). The topic has been reviewed by several authors including CUSHING (1951) and LONGHURST (1976). It is now generally accepted that in most instances migrant forms tend to favour a particular level of subsurface illumination. Thus changes in the intensity of illumination provide the stimulus for migration. Observations made by BODEN and KAMPA (1967) who studied an acoustic scattering layer in the Atlantic Ocean close to the Canary Islands, illustrate this principle clearly. They noted that a steady decrease in surface irradiance commencing approximately one hour before sunset coincided with an upward migration of the sound scattering organisms which were observed to follow precisely the vertical progression of the 5×10^{-4} µW/cm^2 isolume.

Comparable data were obtained during the present investigations, where frame trawl and metre townet sampling has proved conclusively that the small characins Alestes minutus and A. ferox are chiefly responsible for the characteristic midwater scattering layer in Lake Turkana. The project's submersible light meter was insufficiently sensitive to provide in situ measurements at the depth of the layer. However, a significant correlation was obtained between the depth of the scattering layer and that of 1% surface incident light (Chapter 1, Fig. 1.90). The results indicate that A. minutus and A. ferox tended to concentrate at a depth where subsurface illumination was optimal. Marked seasonal and regional differences in turbidity were noted in Lake Turkana (see Chapter 1, page 55). As a consequence the depth of optimal light intensity, and hence the position of the scattering layer, varied considerably. A typical situation appears in Figure 8.20 which shows that during October-November 1975 the depth of the layer varied from within the top 3 m in the turbid waters of the north to more than 30 m in the extreme south. Abrupt changes in transparency which occur in the boundaries of sediment plumes provide a striking illustration of the effect of variations in the photo-environment on the vertical distribution of fish. Figure shows how the scattering layer shifts abruptly upwards through a depth range of 10 m in the transition from clear to relatively turbid water.

The sensitivity of the two species of small Alestes to changes in light intensity was demonstrated by the effects of cloud shadows passing over the surface of the lake. The resulting drop in irradiance produced an immediate response with the scattering layer rising through the water column between 1 and 2 metres over a period of ca 30 seconds. A return to conditions of full illumination was followed by a descent to the original level. Such reactions to changing light intensity form the basis of the vertical migrations of the regular diel pattern observed in the scattering layer during the present studies. A typical sequence of events during the evening ascent in the vicinity of Longech Spit is shown in Fig. 8.78. The observations were made when transparency was comparatively high, with the scattering layer situated at a depth of 8-12 metres during the daytime. Upward migration commenced at approximately 17.00 hrs EAT, 90 minutes before sunset. During the next 60 minutes, as light diminished, the small Alestes ascended steadily through the water column. By 21.00 hrs they had entered the top 4 metres where unfortunately, for technical reasons, the echo sounder was incapable of tracking them further. The records (Fig. 8.78) indicate that for the next 60 minutes the scattering layer lay close to the surface.

With the gradual onset of total darkness at approximately 19.00 hrs echo traces began to re-emerge from the surface layers to form a broad band extending from the upper limits of detection to a depth of 8 metres. The band was more diffuse than the characteristic daytime scattering layer and the acoustic evidence suggests that small Alestes tended to disperse more widely through the water column at night than by day. This view is supported by frame trawl data (Fig. 8.35) which show that the nocturnal range of A. minutus and A. ferox encompasses the whole of the upper layers including the top 4 metres which were not sampled acoustically. The observations indicate that the small fish followed a particular isolume to the surface and that when illumination fell below the critical level, diurnal mechanisms for photo-orientation were suspended. This resulted in the downward dispersal noted after dark. Dawn records suggest that with the onset of daylight the above sequence was followed in the reverse order.

During the total eclipse of the sun which took place on 30th June 1973 at 16.00 hrs EAT, echo records (Fig. 8.78) show that the scattering layer responded to decreasing light in a manner similar to that of normal evenings. This is further proof that endogenous rhythms are not involved.

Although it was possible to follow diel movements of small Alestes from echo traces with confidence, this was not the case where other forms were concerned. Various types of trace have been identified with particular species, as will be discussed in the succeeding section, but usually only under a limited range of conditions. However, the openwater surveys have provided enough evidence of the diel movements of various species for certain conclusions to be drawn.

Lates longispinis and Schilbe uranoscopus are also midwater species which follow the typical pattern of diel vertical migration. Both are predators and their position in the water column underneath the small Alestes spp. follows the rule that in pelagic communities there is a tendency for both trophic level and size to increase with depth. Although in relatively shallow situations the vertical range of L. longispinis and S. uranoscopus impinges on the bottom, (Figs. 8.31-33) they are fully pelagic in deeper regions of the lake, occurring on the lower fringes of the midwater scattering layer (Fig.8.34).

The diel series of observations (Fig. 8.35) indicates that under the conditions of relatively high transparency prevailing during sampling, neither L. longispinis nor S. uranoscopus reached the surface layers during their nocturnal movements although they overlapped with the small Alestes in vertical distribution. It is difficult to establish whether the vertical migrations of the two predatory species were direct reactions to the movements of food organisms or whether, as in A. minutus and A. ferox, the stimulus was provided by the rise and fall of an optimum isolume, lower in intensity than in the previous case.

Frame trawl data (Fig. 8.35) for the demersal species Bagrus bayad suggested a pattern of diel behaviour similar to pelagic forms with a proportion of the population moving away from the bottom at night into the midwater layers. An echo recording obtained in water 60 m deep at Central Island indicates, however, that the mid-water movements involved relatively short incursions into the pelagic zone on the part of individual fish apparently lasting no more than 10 minutes. During such manoeuvres fish swam up to 30 m above the lake bed. Stomach analyses (Chapter 10) show that food intake was greater by night than by day and presumably the nocturnal behaviour pattern was associated with feeding. These observations do not resolve the problem of what provides the stimulus for the diel changes in behaviour in B. bayad. The fact that levels of illumination differ considerably with depth does not rule out the evening lowering of light intensity as a controlling factor since it is probable that individual B. bayad were conditioned to ambient light intensity at any depth. The two other offshore demersal species Haplochromis macconneli and Barbus turkanae showed no tendency to move away from the bottom at night.

Diel patterns of vertical distribution in the characins A. baremose and H. forskalii, which occurred in surface layers of the lake, differed considerably. Results suggest that A. baremose was restricted to the top 4-8 metres of the water column and remained in this depth zone throughout the full 24 hr period. Hydrocynus forskalii ranged more extensively during the daytime extending downwards to the scattering layer. Observations suggest that fish congregated briefly on the surface at dusk before undergoing a short downward dispersion into the midwater layers (Fig. 8.35). Metre townet data proved that the post-larvae of Engraulicypris stellae together with the earliest stages of the prawns Macrobrachium niloticum and Caridina nilotica similarly migrate downwards from the surface layers at night (Figs. 8.47 and 8.48). It seems highly probable that as in the case of A. minutus and A. ferox, the diurnal range of these surface forms coincided with optimum levels of illumination. With the approach of sunset, light intensity at the surface would fall below the optimum level relatively quickly resulting in the suppression of diurnal behaviour patterns and the onset of downward migration.

Vertical distribution in Synodontis schall showed no consistent pattern and varied from survey to survey. There is, however, ample proof that this species was a regular inhabitant of the midwater layers, occurring at times abundantly.

The present investigations have established that light intensity is the prime factor controlling the vertical distribution of most fish in Lake Turkana, either directly or indirectly through interactions between species.

The evolutionary significance of the migrations is difficult to assess. Biological data show that diel movements were accompanied by changes in feeding,both in the food items selected and in intensity. In several instances the observed pattern of vertical distribution clearly separated prey species from potential predators. This was particularly striking in the diurnal behaviour of Engraulicypris stellae and prawns where an obvious break in vertical distribution always coincided with the position of the midwater scattering layer where Alestes minutus and A. ferox were concentrated.

Apart from upward and downward shifts within the water column vertical migration also provided the opportunity for species which were confined to deeper water by day, to make nocturnal incursions into marginal areas of the lake by moving horizontally within the surface layers. Shore seine samples collected after dark often contained forms such as Alestes ferox and Lates longispinis which never occurred in littoral catches during the hours of daylight. As would be expected, the frequency of such occurrences was higher in areas where the shore shelved relatively steeply and the horizontal distances involved were thus shorter. Seine net catches from Longech Spit indicated that Hydrocynus forskalii, the principal daytime predator, tended to be replaced by Bagrus bayad and Schilbe uranoscopus after dark as a result of this type of lateral movement. The withdrawal of H. forskalii from inshore waters during the night is in accordance with the reversed vertical migration pattern of this species demonstrated above.

It is of interest to note that in the exceptionally opaque water of Ferguson's Gulf where light-penetration was drastically attentuated (see Chapter 1, page 52) Bagrus bayad occurred during the daytime at a depth of 2-3 metres compared with a minimum of 10-15 metres in adjacent areas of the open lake. The two populations probably intermingled after dark.

The effects of changing turbidity on the depth of the midwater scattering layer was considered earlier in this discussion. Such effects involved not only the small Alestes which form the scattering layer, but virtually all openwater fish. The seasonal increases in turbidity which were a characteristic feature of Lake Turkana, particularly in northern areas, resulted in a marked rise in the level of the scattering layer. The movement of A. minutus and A. ferox towards the surface was accompanied by a horizontal spread of the small fish into shallower water inshore. Other openwater fish, both demersal and pelagic, underwent a corresponding increase in range so that their position relative to the midwater scattering layer was maintained. The extent of these inshore movements varied considerably from area to area. Maximum effects were noted in the Central Sector of the lake where the scattering layer rose and fell through a depth range of 12-15 metres. This fluctuation resulted in the inshore limits of the scattering layer moving seasonally inshore and offshore over a distance of up to 6 km in the Longech Spit area.

Consistently high bottom trawl catches with a predominance of the midwater forms Lates longispinis, Synodontis schall and Schilbe uranoscopus were recorded in areas where a well-marked scattering layer came into contact with the lake bed. The concentration of fish under such circumstances was probably due to the constraints imposed on vertical migration by the lake bed. In deeper water the three species were dispersed more widely through the water column. Midwater fish were difficult to catch under normal circumstances and the zone of contact between scattering layer and lake bed would be of considerable importance if the commercial exploitation of pelagic stocks was undertaken.

It is convenient at this point to compare the present results with observations made on pelagic species in other African lakes. In Lake Tanganyika two clupeids _Limnothrissa miodon_ (Boul.) and _Stolothrissa tanganicae_ Regan occupy the niche filled by _Alestes minutus_ and _A. ferox_ in Lake Turkana, and likewise migrate towards the surface at night. However, the behaviour pattern in the clupeids differs considerably. WOODWARD (1974) showed that during the hours of daylight the clupeids concentrated in dense but widely scattered shoals which were represented on echo records as tall slender plume traces. The shoals were situated at depths of 10-20 metres in shallow water, but in deep water offshore they extended downwards to a maximum of 60 metres. At dusk there was an upward movement as shoals dispersed and formed a continuous but diffuse layer in the top 16 to 25 metres which persisted throughout the hours of darkness. This nocturnal pattern closely resembled that of the small characins in Lake Turkana and it was in diurnal behaviour that pelagic fish in the two lakes diverged most widely.

REYNOLDS (1970) described the vertical migration patterns of small fish in the newly formed Lake Volta, principally the clupeid _Pellonula afzelusi_ (Johnels) and the Schilbeid _Physailia pellucida_ Boul. Diurnal echo records revealed no fish traces until the late afternoon when irregular aggregations representing shoals appeared on the bottom and moved slowly upwards to reach the surface after dark. Once on the surface the shoals tended to disperse through the upper layers in a manner reminiscent of pelagic fish in Lakes Turkana and Tanganyika. In his discussion Reynolds reported that echo surveys of Lake Volta made in 1969 subsequent to his own investigations had revealed the presence of a considerable scattering layer both by day and by night chiefly at depths between 10 and 20 m, which might represent fish. Presumably these traces represented a species which had colonised the open water since the original study period. From the description, this scattering layer closely resembles the layer formed by _Alestes minutus_ and _A. ferox_ in Lake Turkana and it is possible that the manifestation may represent an invasion of the open waters of Lake Volta by an _Alestes_ such as _A. nurse_ or _A. leuciscius_. A precedent exists for such colonisation of a newly formed African lake; WOODWARD (_op. cit._) relates how _A. lateralis_ started to spread into the open waters of Lake Kariba until apparently checked by the introduction of _Limnothrissa miodon_. Apart from Lake Volta, acoustic scattering layers similar to that of Lake Turkana have not been reported from other African lakes and there are no records of small _Alestes_ forming truly pelagic communities elsewhere.

SUMMARY

The patterns of diel vertical migration of various fish observed during the present studies are compared with results from elsewhere. It is concluded that light intensity is the environmental factor chiefly concerned.

Seasonal and regional variations in the vertical zonation of fish are also discussed and it is shown that modifications to the light climate, resulting from changes in the turbidity, are responsible for the observed phenomena.

APPRAISAL OF THE OPENWATER SURVEY RESULTS

A J Hopson and A A Q R McLeod

INTRODUCTION

QUALITATIVE EVIDENCE

QUANTITATIVE ESTIMATES

Correlations between acoustic and absolute densities

Demersal species

Large pelagic species

Small pelagic species

STANDING STOCK ESTIMATES

SUMMARY

INTRODUCTION

The earlier sections of this chapter have provided information on the distribution and biomass of openwater fish, obtained with various types of gear including bottom trawls, midwater trawls, townets, gillnets and acoustic equipment. There is generally close agreement on the pattern of distribution in the constituent species of fish, but estimates of standing stock obtained from different types of gear often vary considerably. The purpose of the present section is to review the results with the object of drawing firm conclusions where complementary evidence exists and to attempt to reconcile conflicting data.

QUALITATIVE EVIDENCE

The species composition of the openwater ichthyofauna has been established satisfactorily by the present surveys. Where the various types of gear sampled common ground, qualitatively similar results were obtained. It should be stressed, however, that the breakdown of acoustic estimates of standing stock of species was based on bottom trawl data and does not provide an independent assessment of catch composition.

In the deeper waters of the lake Bagrus bayad, Haplochromis macconneli and Barbus turkanae were clearly the chief demersal species occurring ubiquitously in bottom trawl catches (Table 8.5) but appearing in pelagic hauls with midwater trawl, frame trawl and metre townet only when the gear impinged on the bottom four metres. The pelagic gear confirms that other species, which at times formed a high proportion of the demersal trawl catch, including Schilbe uranoscopus, Lates longispinis and L. niloticus, also ranged widely in the midwater layers.

Frame trawl and metre townet data, supported by evidence from the Boris midwater trawl, prove conclusively that Alestes minutus and to a lesser degree A. ferox were responsible for the midwater scattering layer in Lake Turkana. These small fish form a vitally important link in the openwater food chains between zooplankton and larger predators. Results from the metre townet show that a third species of small pelagic fish, *Engraulicypris stellae*, was widely dispersed throughout the water column between the scattering layer and the bottom, together with the adult stages of two prawns, *Macrobrachium niloticum* and *Caridina nilotica*.

Information from the various sources relating to the distribution of fish in the surface layers was consistent. *Hydrocynus forskalii* and *Alestes baremose* were the principal species involved. Pelagic gear proved that *H. forskalii* commonly ranged downwards into the midwater layers where, as shown by food studies (see Chapter 9, page 760), *Alestes minutus* was preyed on extensively. Catch data, however, suggested that *A. baremose* tended to remain near the surface at all times.

Bottom trawl catches provided most of the information on the extent to which inshore fish ranged into deeper water. *Labeo horie* regularly occurred down to the 20 m contour but *Sarotherodon niloticus* was confined almost entirely to depths of less than 10 m. These observations are supported by data from bottom-set gillnets (Table 8.24). Trawl and townet data from all sources prove that *Citharinus citharus* occurred only extremely rarely within the survey area, even during the initial stages of the present investigations when the species dominated commercial catches. It seems likely that *C. citharus* was chiefly confined to the commercial fishing grounds on the west coast of the North and Central Sectors, but surface set gillnet results indicate that the species also occurred sparingly within the 10 m contour on the east coast.

Bagrus docmac was an uncommon demersal species in bottom trawl catches, usually associated with hard substrates. Gillnet data from the southern basin (Table 8.26 h) suggest that the fish may be relatively frequent on rocky coasts within the 20 m contour in the south of the lake where bottom trawling was impracticable.

QUANTITATIVE ESTIMATES

CORRELATIONS BETWEEN ACOUSTIC AND ABSOLUTE DENSITIES

Quantitative estimates of biomass in absolute terms were derived from bottom trawl, frame trawl and metre townet data. These estimates have been augmented considerably by results from the acoustic survey which have yielded information on both demersal fish and pelagic species occurring in the midwater scattering layer. The acoustic data do not provide a truly independent estimate of demersal standing stock since the results in absolute terms were based on a correlation between bottom trawl catches and acoustic densities recorded simultaneously. *Bottom trawl and acoustic estimates of standing stock are thus based on a common proviso - that the standard bottom trawl had a wing-to-wing opening of 10 m and that its catching efficiency was 100% between the wings.* Any divergence of the gear parameters from the stated values will have errors in the calculated values of biomass.

Table 8.27 shows acoustic biomass estimates of the demersal population in both relative and absolute terms for three separate surveys. The ratios between the two values varies from 1:11.24 to 1:12.52 with a mean of 1:11.75. The differences are due to the fact that the catch/integral regression line (see page 630) did not pass through the origin. By applying the mean ratio of 1:11.75 to the estimates of relative biomass for the midwater scattering layer (Table 8.27), tentative values of absolute biomass for the midwater scattering layer in the acoustic survey area have been obtained (Table 8.29). As indicated previously, estimates of biomass for November 1974 over the survey area as a whole were affected by the seasonal rise of the midwater scattering layer into the upper 10 m of the water column where, due to the limitations of the acoustic gear, measurements could not be recorded. For this reason a separate assessment has been made of the acoustic biomass in the region of the lake where the scattering layer was situated below a depth of 10 m during November 1974 (see Table 8.29), a total area of approximately 4703 km^2. A direct comparison of biomass for the three surveys is provided in Table 8.29 where areal densities have been calculated. It should be stressed that in the absence of information on the relative target strengths of pelagic and demersal fish, the density estimates in Table 8.29 must be regarded as very approximate and subject to considerable revision as more information becomes available. The lakewide patterns of distribution of pelagic fish in the midwater scattering layer revealed by the acoustic survey (Fig. 8.79) may, however, be interpreted without such reservations. Variations in stock density indicated by the isopleths are expressed in relative terms but probably represent gradients in absolute density of a similar magnitude.

DEMERSAL SPECIES

Quantitative estimates of stock density from different openwater surveys have been summarised in Table 8.30. Since the areas involved varied, biomass has been expressed in terms of areal density (kg/km^2). The estimates relate only to that portion of a total stock which is liable to capture by a particular type of gear.

The most consistent results were obtained for the main demersal species Bagrus bayad, with areal densities ranging from 938 kg/km^2 in the acoustic survey to 1282 kg/km^2 in the frame trawl. Bagrus bayad of over 45 cm TL were not represented in the frame trawl catches (see page 607) and smaller fish were retained in the 19 mm stretched mesh cod end than was the case in the 38 mm mesh of the bottom trawl. Thus frame trawl and bottom trawl results are not strictly comparable, although in each case a high proportion of the catch was formed of fish with a similar size range of ca 10-45 cm FL. The affects of mesh selectivity are also evident in results for a second deep water demersal species, Haplochromis macconneli which attained a maximum size of only 13 cm FL. Densities of 9-12 kg/km^2 were indicated by the bottom trawl and acoustic observations (Table 8.30) but a value of 109 kg/km^2 was calculated from data for the frame trawl, which sampled populations of this small fish more effectively.

LARGE PELAGIC SPECIES

It is generally accepted that standing stock estimates are more difficult to obtain from catch data for pelagic stocks than is the case with demersal stocks. Marked discrepancies in values for pelagic species in Table 8.30 show that the present survey was no exception.

As discussed at length above (see page 643) certain species occurred regularly in the bottom 4 m but also ranged upwards to the midwater scattering layer, particularly at depths of less than 30 m. These species included Barbus bynni, Schilbe uranoscopus, Chrysichthys auratus, Synodontis schall, Lates longispinis and Lates niloticus. Estimates of areal densities based on uncorrected bottom trawl and acoustic data (Table 8.30, columns 3, 4 and 5) provide an index of stock abundance for fish situated within 4 m of the lake bed which were thus accessible to the bottom trawl, i.e. the trawlable stock. For the present purposes the trawlable stock density may be regarded as a minimum value of probable stock densities for the species concerned. A comparison of results for the bottom trawl survey at depths greater than 10 m, with the acoustic estimates (Table 8.30, columns 2 and 3) shows that the value of stock density obtained from the trawl data was approximately 44% higher. This difference may be due to a variety of causes. The acoustic surveys were all made during the period June-November* which corresponded with the early, main and late phases of the Omo flood season. Most species of demersal fish showed a tendency to be more concentrated within the 10 m contour at the north end of the lake at the time of the flood season. It is possible that during each of the acoustic surveys, areas of deeper water to the south of the 10 m contour had become somewhat depopulated. The bottom trawl estimates were based on data combined from all months, and seasonal trends would tend to become obscured. This could result in the higher estimate of stock density noted in the trawl results. Interspecific differences in the acoustic target strengths of fish would also lead to a discrepancy between the two estimates of stock density if the species composition of trawl samples on which the catch/echo integral regression was based was atypical of the survey area as a whole.

Corrected estimates of stock density for the species which occurred regularly both in demersal trawl catches and in pelagic gear are shown in Table 8.30 (column 4). The values have been extrapolated from bottom trawl data using a correction based on frame trawl data (see page 604), and provide an integral measure of stock occurring at all levels in the water column. In most of the species concerned, the fraction of the population dispersed through the midwater layers was from approximately one to two times greater than the demersal fraction, but in the case of Synodontis schall the results suggest that 90% of the stock occurred off the bottom. Directly comparable estimates for the same species derived from full water column oblique frame trawl catches (Table 8.30, column 5) are considerably lower than the corrected bottom trawl results, with the exception of Schilbe uranoscopus. However, if the distribution of oblique frame trawl stations (Fig. 8.42) is compared with the midwater scattering layer density contours (Fig. 8.79), it will be seen that there was an almost complete lack of frame trawl data from west coast areas, particularly in the Central Sector, where acoustic densities of pelagic fish were considerably higher than elsewhere. The failure of the frame trawl to provide adequate coverage of areas where densities of pelagic fish were normally high is probably the chief reason for the wide discrepancy between corrected bottom trawl and frame trawl results. The bottom trawl values (Table 8.30, column 8) are therefore regarded as more realistic estimates of the stock densities of the six species concerned: Barbus bynni. Schilbe uranoscopus, Chrysichthys auratus, Synodontis schall. Lates longispinis and Lates niloticus.

*A survey scheduled for April 1975 had to be abandoned when R V Halcyon was withdrawn from service for overhaul.

Very high standing stock densities of the order of 37000 kg/km^2 were suggested by the acoustic survey for pelagic fish occurring in a 10 m depth slice which contained the midwater scattering layer (Table 8.30, column 6). A proportion of fish included in this estimate were undoubtedly representatives of the six larger species considered in the preceding paragraph, which, it is calculated from Table 8.30 (columns 2 and 4), were present in the midwater layers at a combined density of ca 6200 kg/km^2. Since the 10 m depth layer sampled acoustically usually included much of the water column between the midwater scattering layer and the demersal layer in areas of the lake where acoustic densities were high, it has been assumed that the density of 6200 kg/km^2 is also accounted for in the total acoustic density estimate of 37000 kg/km^2.

SMALL PELAGIC SPECIES

Relatively high areal densities of small pelagic fish are indicated by the metre townet data (Table 8.22). The peak value was recorded for Engraulicypris stellae but it has been proved conclusively (see page 611) that due to the small size of this fish, individual echoes were not discriminated by the acoustic gear above the noise level. Since the bulk of the offshore population consisted of individuals scattered through the deeper waters of the lake, the contribution made by this species to echo integrals was negligible. It is considered that the density of 1799 kg/km^2 quoted for E. stellae in Table 8.30 is a satisfactory estimate of the open water population of this fish. As shown in the biological study (see Chapter 9) adult E. stellae also occurred abundantly in the littoral region of the lake.

Lates spp. post-larvae were similarly too small and widely scattered to be included in the echo integrals. The metre townet apparently sampled the population effectively and a density of 45 kg/km^2 (Table 8.30) is probably realistic.

Micralestes acutidens and various post-larval and juvenile fish which fall into the category 'others' (Table 8.30) were chiefly recorded in metre townet samples from shallow water in the Northern Sector outside the acoustic survey area (see Table 8.22).

Alestes minutus and Alestes ferox have proved to be the species chiefly responsible for the characteristic echo trace of the midwater scattering layer and results indicate that the fish also formed a high percentage of the pelagic biomass. The proportion of the standing stock formed by each species is difficult to estimate. Escapement of A. minutus (maximum size 3 cm FL) was high in the 19 mm cod end of the frame trawl and densities of A. ferox, which attained a length of over 10 cm, were 50% higher in this net (Table 8.30). In the metre townet, however, A. ferox tended to escape by virtue of its larger size and catches of A. minutus were 27 times higher. From these observations it seems probable that A. minutus formed the major portion of the biomass of pelagic Alestes, and for the purpose of the present investigations it is assumed that the biomass of this species was ten times greater than that of A. ferox.

Estimates of stock density thus obtained for A. minutus and A. ferox from metre townet data amount to approximately 1700 kg/km^2 which is extremely low compared with the mean value of over 30000 kg/km^2 suggested by the acoustic survey of the midwater scattering layer. However, distribution charts for metre townet catches (Figs. 8.49-60) indicate that, as with the frame trawl survey, a very low proportion of townet samples were collected near the west coast of the lake from Kerio northwards, where the acoustic survey (Fig. 8.70) shows that the midwater scattering layer was most concentrated. Thus in the Central Sector a mean stock density of 508 kg/km^2 was recorded from a total of 96 hauls. Only 9 of the hauls were made in the western third of the sector in areas of relatively high acoustic density. The acoustic data indicate that there was a 300-fold difference in stock density between the areas demarcated by lowest and highest contours in the acoustic survey charts (Fig. 8.79). The following mean values of acoustic density were recorded during the June 1975 survey:

Density contour	Mean density	(SD)
0.5	0.15	(0.15)
0.5–2	0.94	(0.42)
2–5	3.19	(0.89)
5–20	9.33	(4.16)
20	45.42	(23.66)

With a density range of this order it is reasonable to accept that the difference between the lakewide estimate of 1700 kg/km^2 obtained for small pelagic Alestes from the metre townet results, and the acoustic estimate of ca 34000 kg/km^2 was due to sampling inadequacies in the net survey. The actual existence of high stock densities of A. minutus in the lake is indicated by data from the 10–20 m zone in the Northern Sector where, from a total of 23 samples, a mean density of 9880 kg/km^2 was recorded.

Relatively little data are available on the abundance of midwater fish in other large African lakes, but an acoustic survey of Lake Tanganyika provided an estimate of 8800 kg/km^2 for pelagic stocks (COULTER, 1977), over twice the value suggested by acoustic observations on Lake Turkana. The structure of pelagic populations in Lake Tanganyika closely resembled those investigated during the present survey, with the bulk of the biomass consisting of small, short-lived (annual mortality rate 99%), zooplanktivorous fish.

The overall distribution pattern of pelagic fish revealed by the present acoustic survey, with a heavy concentration of biomass to the west of the lake, is a striking feature of Lake Turkana. An explanation of this phenomenon is discussed at length in Chapter 12 (see page 1519). It seems probable that surface currents generated by the strong prevailing south-easterly winds result in a north-westerly drift of planktonic food which subsequently concentrates in the areas of high pelagic fish densities.

No attempt has been made to calculate the stock densities of Hydrocynus forskalii or Alestes baremose, the two principal surface species in the openwaters of Lake Turkana. A value of 180 kg/km^2 for H. forskalii in the lakewide bottom trawl results (Table 8.7) must be regarded as well below a minimum estimate for this fish. The gillnet survey indicates that Alestes baremose was a widespread, and at times very abundant, species in the surface waters of Lake Turkana, and its comparative scarcity in all types of active gear suggests avoidance as a result of fright reaction to the passage of the ship.

Distichodus niloticus, Labeo horie and Sarotherodon niloticus occurred regularly in trawl catches from the shallowest depth zones, but the populations of these fish centred on areas outside the open water survey area and the present data provide no clue to overall stock abundance.

STANDING STOCK ESTIMATES

On the basis of the conclusions regarding stock densities reached in the foregoing discussion, tentative estimates of standing stock are presented in Table 8.31. The assumptions on which the estimations of stock density were based should be taken into consideration when viewing the present calculations. The predictions are limited to those species which were amply covered by the surveys and include most of the important openwater species with the exception of Hydrocynus forskalii and Alestes baremose. Standing stock was calculated for areas of the lake below the 10 m contour using the most appropriate value of stock density for each species to which has been added an estimate of biomass in water shallower than 10 m based on information in column 3 of Table 8.30. In the case of Barbus bynni the population sampled consisted chiefly of immature fish and a higher proportion of the total biomass was probably located in the commercial fishing grounds on the west shore of the Central and Northern Sectors outside the survey area.

SUMMARY

Data from various surveys are compared and discussed. It is concluded that the results obtained by different techniques are reasonably consistant and that where marked divergences are evident, sampling inadequacies are the most likely explanation. Midwater trawl, frame trawl and metre townet surveys all failed to sample areas to the west of the lake, where from acoustic results it is evident that by far the highest densities of pelagic fish occurred.

On the basis of information from the different surveys, estimates of standing stock for certain species of open water fish are made. The results show that the predominant species in terms of biomass is Alestes minutus. Two important pelagic species, Hydrocynus forskalii and Alestes baremose are excluded from the estimates, however, due to the lack of quantitative data.

REFERENCES

ALVERSON, D L and PEREYRA, W T (1973). Demersal fish populations in the northeastern Pacific Ocean - an evaluation of exploratory fishing methods and analytical approaches to stock size and yield forecasts. J. Fish. Res. Bd. Can. 26 : 1985-2001

BERGSTRAND, E and CORDONE, A J (1971). Exploratory bottom trawling in Lake Victoria. Afr. J. Hydrobiol. Fish. 1 : 13-23

BODEN, B P and KAMPA, E M (1967). The influence of natural light on the vertical migrations of an animal community in the sea. Symp. zool. Soc. (Lond.) 19 : 15-26

COULTER, G W (1977). Approaches to estimating fish biomass and potential yield in Lake Tanganyika. J. Fish. Biol. 11 : 393-408

CUSHING, D H (1951). The vertical migration of planktonic crustacea. Biol. Rev. 26 : 158-192

DRAGESUND, O and OLSEN, S (1965). On the possibility of estimating year class strength by measuring echo abundance of 0-group fish. Fisk Dir. Skr. (Havunders) 13(8) : 47-75

EHRENBERG, J E and LYTLE, D W (1972). Acoustic techniques for estimating fish abundance. I.E.E.E. Trans. Vol. GE10 : 138-145

FAO (1978). Report on the group of experts on target strength, ACMRR (in preparation).

HOLNESS, A P J (1969). Report on the echo sounding depth survey of part of central Lake Rudolf 22nd July - 26th July 1969. Fisheries Department, Nairobi (mimeographed) 14 pp

NOCKELS, J E I (1976). Report on the calibration and operation of the Triton fish echo processing equipment used in the 1972-75 survey of Lake Turkana together with details of modifications carried out on the gear. Ministry of Overseas Development, London (mimeographed) 66 pp

LONGHURST, A R (1976). Vertical migration. In The ecology of the seas. Eds. Cushing, D H and Walsh J J, Oxford. Blackwell, 467 pp

PEARSON, N D and MITSON, R B (1973). Electro-acoustic systems to aid the analysis of pelagic and demersal fish stocks. I.C.E.S. Symp. acoustic methods in fisheries research. No.28 : 9 pp

REYNOLDS, J D (1971). Biology of the small pelagic fishes in the new Volta Lake in Ghana. II Schooling and migrations. Hydrobiologia 38 : 79-91

TURNER, J L (1977). Some effects of demersal trawling in Lake Malawi (Lake Nyasa) from 1968 to 1974. J.Fish.Biol. 10 : 261-271

WELSBY, V G (1975). The acoustic target strength of live fish. Results of the "easdale" project and some theoretical considerations. Proc. spec. meet. I.O.A. 1975 7pp

WOODWARD, J G (1974). Successful reproduction and distribution in Lake Kariba. In Lake Kariba: a man-made tropical ecosystem in Central Africa 526-641. Eds. Balon, E K and Coche, A G, The Hague, Junk. 676pp

WORTHINGTON, E B and RICARDO, C K (1936). Scientific results of the Cambridge Expedition to the East African lakes 1930-31. No. 17 The vertical distribution and movements of plankton in Lakes Rudolf, Naivasha, Edward and Bunyoni. J. Linn. Soc. Zool. 40 : 33-69

TABLE 8.1

Comparison of the efficiency of the 'Victoria' bottom trawl and the 3-bridled bottom trawl based on catches of *Bagrus bayad* from the Central Sector of the lake during the period up to February 1974. Catch per effort is expressed in kg/hr.

Depth zone (m)	'Victoria trawl		3-bridled trawl		Ratio
	Mean catch per effort	Number hauls	Mean catch per effort	Number hauls	Victoria C/E: 3-bridled C/E
20-25	28	12	43	8	1.54
25-30	24	10	32	2	1.33
30-40	31	9	43	6	1.39
40-50	50	11	60	2	1.20
50-60	32	5	58	4	1.81
60-70	62	4	-	-	-
70-80	79	4	105	3	1.33
80+	106	3	-	-	-
				Mean	1.43

TABLE 8.2

A summary of all hauls made during the bottom trawl survey of Lake Turkana showing the number of tows in each category

Category	'Victoria' trawl	3-bridled trawl	Danish fish trawl	All bottom trawls
Quantitative hauls:				
1972	84	0	0	84
1973	55	90	0	145
1974	0	82	0	91
1975	0	21	0	21
All years	139	193	9	341
Non-quantitative hauls:				
Net obstructed or torn	9	5	1	15
Net incorrectly rigged	1	3	1	5
Hauls for live fish	0	16	0	16
Equipment trials	0	4	0	4
Night hauls	0	4	0	4
Total all categories	149	225	11	385

TABLE 8.3

Showing the number and percentage of quantitative bottom trawl hauls made in each depth zone together with an estimate of the area of lake bed lying in the zone

Depth zone (m)	Area (km^2)	% total area	Number of tows	% total tows
0-10	1619	21.4	54	15.8
10-20	1199	15.8	81	23.7
20-30	1269	16.7	82	24.0
30-40	1005	13.2	36	10.5
40-50	698	9.2	20	5.8
50-60	808	10.6	24	7.0
60-70	529	7.0	24	7.0
70-80	269	3.5	13	3.8
80+	160	2.0	7	2.0
	7560		341	

TABLE 8.4

Showing total weight in kg of all species of fish caught in quantitative bottom trawl hauls during the entire 1972-75 survey period. Percentage weights are also shown for each species

Species	Weight (kg)	% weight
Hydrocynus forskalii	1471	3.9
Alestes baremose	105	0.3
Alestes dentex	4	+
Alestes ferox	231	0.6
Citharinus citharus	1	+
Distichodus niloticus	157	0.4
Labeo horie	300	0.8
Barbus bynni	1715	4.6
Barbus turkanae	10	+
Schilbe uranoscopus	587	1.6
Bagrus bayad	8811	23.5
Bagrus docmac	114	0.3
Chrysichthys auratus	208	0.6
Clarias lazera	5	+
Malapterurus electricus	1	+
Synodontis schall	8018	21.4
Lates niloticus	8867	23.6
Lates longisipinis	6377	17.0
Sarotherodon niloticus	420	1.1
Sarotherodon galilaeus	1	+
Tilapia zillii	18	+
Haplochromis macconneli	92	0.2
Haplochromis rudolfianus	1	+
Tetraodon fahaka	2	+
TOTAL	37,516	

TABLE 8.5

Mean catch per unit effort in kg/hr for all species of fish caught in 341 quantitative hauls with bottom trawls at different depths between June 1972 and August 1975.

Depth in metres	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	Over 80
Number of hauls	54	81	82	36	20	24	24	13	7
Hydrocynus forskalii	20	15	6	2	+	1	1	+	+
Alestes baremose	4	+	+	+	+	+	+	+	-
Alestes dentex	+	+	-	-	-	-	-	-	-
Alestes ferox	1	2	2	+	+	+	+	+	+
Citharinus citharus	+	-	-	-	-	-	-	-	-
Distichodus niloticus	6	1	-	-	-	-	-	-	-
Labeo horie	7	4	1	+	+	-	-	-	-
Barbus bynni	26	16	9	2	2	+	1	1	+
Barbus turkanae	-	+	+	+	+	+	+	+	-
Schilbe uranoscopus	1	3	8	3	1	1	+	+	1
Bagrus bayad	19	45	53	62	70	51	69	111	109
Bagrus docmac	2	1	+	-	-	-	-	-	-
Chrysichthys auratus	+	3	1	1	+	+	+	+	-
Clarias lazera	-	-	-	+	-	-	-	-	-
Malapterurus electricus	-	+	-	-	-	-	-	-	-
Synodontis schall	71	109	56	7	+	3	1	2	2
Lates longispinis	16	55	85	25	10	5	4	+	+
Lates niloticus	127	55	57	23	27	19	5	-	-
Haplochromis macconneli	+	+	+	+	1	1	1	2	2
Haplochromis rudolfianus	+	-	-	-	-	-	-	-	-
Sarotherodon niloticus	22	+	+	-	-	-	-	-	-
Sarotherodon galilaeus	+	-	-	-	-	-	-	-	-
Tilapia zillii	+	+	+	-	-	-	-	-	-
Tetraodon fahaka	+	-	-	-	-	-	-	-	-
Total	323	314	279	127	113	83	82	117	114

TABLE 8.6

The coefficient of variation for twelve species of fish caught in a total of 341 quantitative hauls with bottom trawls at different depths between June 1972 and August 1975.

Depth in metres	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	Over 80
Number of hauls	54	81	82	36	20	24	24	13	7
Hydrocynus forskalii	131	150	250	150	160	180	170	+	+
Distichodus niloticus	260	480	-	-	-	-	-	-	-
Labeo horie	160	290	510	+	+	-	-	-	-
Barbus bynni	149	228	280	160	180	210	220	180	+
Schilbe uranoscopus	350	280	390	200	120	180	240	+	+
Bagrus bayad	181	97	106	68	98	75	77	55	72
Bagrus docmac	450	450	560	-	-	-	-	-	-
Chrysichthys auratus	410	350	280	310	+	330	+	+	-
Synodontis schall	186	168	176	210	160	200	160	110	+
Lates longispinis	226	151	214	167	348	250	218	+	+
Lates niloticus	139	138	209	151	132	240	300	+	+
Sarotherodon niloticus	336	800	300	-	-	-	-	-	-

+ sample of insufficient size

TABLE 8.7

Estimates of areal densities (in kg/km^2) of fourteen species of fish occurring in bottom trawl catches, based on data from all depth zones, for the three main sectors of the lake. Values of c_h and c_v were taken as unity and no correction for fish occupying the midwater layers has been applied (see text).

	Areal densities (kg/km^2)				Total biomass (tonnes)
Sector	North	Central	South	Total	
Grid rows	A-G	H-R	S-Y		
Area (km^2)	2288	3702	1570	7560	
Hydrocynus forskalii	414	89	54	180	1361
Alestes baremose	6	8	2	6	45
Distichodus niloticus	13	16	8	13	98
Labeo horie	37	20	2	22	166
Barbus bynni	121	126	64	112	847
Schilbe uranoscopus	109	64	22	69	522
Bagrus bayad	1226	1014	668	1006	7605
Bagrus docmac	106	14	18	43	325
Chrysichthys auratus	45	17	11	24	181
Synodontis schall	596	506	252	481	3636
Lates longispinis	368	573	219	437	3304
Lates niloticus	1583	637	485	892	6744
Haplochromis macconneli	3	14	8	9	68
Sarotherodon niloticus	1	47	16	26	197
Others	42	18	+	21	159
Total	4669	3163	1828	3341	25258

TABLE 8.8

Estimates of standing stock of the principal species of fish in tonnes occurring in Lake Turkana at depths greater than 10m based on bottom trawl data for each of six sub-sectors. Values of c_h and c_v were taken as unity and no correction for fish occurring in the midwater layers has been applied (see text).

Sector	North		Central			South		
Grid rows	A-D	E-G	H-K	L-M	N-R	S-Y	Total	% total
Area (km^2)	306	933	1480	587	1159	1477	5942	biomass
Hydrocynus forskalii	65	98	94	26	90	71	444	2.6
Labeo horie	3	28	1	5	19	3	59	0.3
Barbus bynni	131	54	128	28	128	84	553	3.2
Schilbe uranoscopus	35	44	46	26	149	34	334	1.9
Bagrus bayad	442	1001	1526	795	1337	1048	6149	35.7
Chrysichthys auratus	+	78	25	4	32	18	157	0.9
Synodontis schall	195	239	732	203	527	345	2241	13.0
Lates longispinis	179	577	886	220	955	344	3158	18.3
Lates niloticus	847	1088	949	180	316	442	3845	22.3
Haplochromis macconneli	2	4	23	12	15	12	68	0.4
Others	40	29	25	9	70	43	216	1.3
Total standing stock 10m	1396	3260	4435	1511	3638	2444	17224	

TABLE 8.9

Values of c_v (see text) calculated for different depth zones in the three sectors of the lake for the main offshore species of fish.

Depth zone (m)	10	10-15	15-20	20-25	25	15	15-20	20-25	25-30	30	20	20-25	25-30	30-40	40
Bagrus bayad	1.00	0.87	0.87	0.87	0.87	1.00	0.87	0.87	0.87	0.87	1.00	0.87	0.87	0.87	0.87
Chrysichthys auratus	1.00	0.78	0.64	0.55	0.48	1.00	0.78	0.64	0.55	0.48	1.00	0.78	0.64	0.55	0.48
Barbus bynni) *Lates longispinis*) *Lates niloticus*)	1.00	0.57	0.39	0.30	0.24	1.00	0.57	0.39	0.30	0.24	1.00	0.57	0.39	0.30	0.24
Schilbe uranoscopus	1.00	0.52	0.38	0.28	0.21	1.00	0.52	0.38	0.28	0.21	1.00	0.52	0.38	0.28	0.21
Synodontis schall	1.00	0.14	0.07	0.05	0.04	1.00	0.14	0.07	0.05	0.04	1.00	0.14	0.07	0.05	0.04

TABLE 8.10

Estimates of standing stock of main offshore species of fish caught in bottom trawls, with correction for fish occurring above the headline in the midwater layers based on values of c_v in Table 8.9.

Data have been analysed for depth zones below the 10m contour in six-sub-sectors of the lake. Total biomass for all depths, including the 0-10m zone, and estimates of areal density are given in the last two columns.

	Standing stock below 10 metre contour in tonnes								
Sector	North		Central			South	Total 10m	Total all depth zones	Areal density all depth zones (kg/km^2)
Grid rows	A-D	E-G	H-K	L-M	N-R	S-Y			
Barbus bynni	293	150	318	72	334	106	1273	1564	207
Schilbe uranoscopus	109	131	175	93	553	152	1213	1399	185
Bagrus bayad	509	1150	1750	1020	1356	1190	6975	8614	1139
Chrysichthys auratus	8	101	45	6	47	36	243	263	35
Synodontis schall	2060	3057	8750	1942	9369	3796	28974	30120	3984
Lates longispinis	480	1956	2889	618	3162	1161	10266	10414	1378
Lates niloticus	2895	3519	3148	578	1094	997	12231	15130	2001
Total	6354	10064	17075	4329	15915	7438	61175	67504	8929

TABLE 8.11

Summary of hauls made with the Boris midwater trawl during the period September - November 1975

Category	Number
Abortive	1
Non quantitative	19
*Quantitative hauls :-	
Surface 10 metres, off bottom and excluding midwater scattering layer	16
Surface 10 metres, off bottom and including midwater scattering layer	32
Midwater scattering layer below top 10 metres	22
Upper portion water column between midwater scattering layer and bottom	5
Lower portion water column between midwater scattering layer and bottom	5
Bottom layers in deep water offshore	1
Total quantitative hauls	81
Total hauls	101

* Quantitative hauls were all made during the hours of daylight.

TABLE 8.12

Showing mean catch per effort in both No/hr and kg/hr for 16 Boris midwater trawl tows made in the surface layers (0-10m) where the scattering layer was situated in deeper water below. The catch per effort in kg/hr for each species is expressed as a percentage of the total catch per effort in the final column

	No. of hauls present	No/hr	Size range (cm)	kg/hr(±SD)	% weight
Hydrocynus forskalii	10	5.8	20-51	2.16 (3.15)	22.3
Alestes baremose	4	2.1	3-26	0.05 (0.11)	0.4
Alestes ferox	7	4.2	3-10	0.05 (0.12)	0.5
Alestes minutus	7	157.7	1- 4	0.05 (0.09)	0.5
Lates longispinis	3	0.9	32-43	0.49 (1.12)	5.1
Lates niloticus	2	0.4	89-129	6.90 (23-58)	71.1
Lates post-larvae	2	0.4	1- 2	+	+
TOTAL	16	171.5		9.70	

TABLE 8.13

Showing mean catch per effort in both No/hr and kg/hr for 48 Boris midwater trawl hauls made in the surface layers (0-10m) where the midwater scattering layer was included. Otherwise as Table 8.12

	No. of hauls present	No/hr	Size range (cm)	kg/hr(±SD)	% weight
Hydrocynus forskalii	42	18.0	10-55	4.59 (4.52)	37.7
Alestes baremose	22	1.7	3-41	0.21 (0.35)	1.7
Alestes ferox	39	128.0	2-10	0.49 (0.95)	4.0
Alestes minutus	39	5899.1	1- 4	1.46 (2.76)	12.0
Micralestes acutidens	1	0.1	4	+	+
Labeo horie	2	0.1	3-47	0.05 (0.40)	0.4
Barbus bynni	2	0.1	14-35	0.04 (0.29)	1.0
Engraulicypris stellae	7	1.3	1- 3	+	+
Schilbe uranoscopus	18	22.7	1-27	0.19 (0.38)	1.5
Bagrus bayad	6	0.7	14-35	0.04 (0.29)	0.3
Synodontis schall	16	4.0	1-31	1.17 (3.98)	9.6
Lates longispinis	29	9.8	8-46	1.28 (2.04)	10.5
Lates niloticus	3	0.2	80-129	2.49 (13.65)	20.5
Lates post-larvae	13	11.4	1- 3	0.01 (0.06)	0.1
Haplochromis macconneli	2	0.7	3- 8	+	+
Sarotherodon niloticus	3	0.1	4-26	0.02 (0.08)	0.1
Macrobrachium niloticum	20	147.9	-	0.01 (0.03)	0.1
Caridina nilotica	1	0.6	-	+	+
TOTAL	48	6246.5		12.05	

TABLE 8.14

Showing mean catch per effort in both No/hr and kg/hr for 54 Boris midwater trawl hauls made in the midwater scattering layer including tows in the surface layers (0-10m). Otherwise as Table 8.12

	No. of hauls present	No/hr	Size range (cm)	kg/hr(±SD)	% weight
Hydrocynus forskalii	46	16.9	10-62	4.46 (4.85)	41.8
Alestes baremose	21	1.5	3-41	0.19 (0.35)	1.8
Alestes ferox	48	142.8	2-10	0.58 (0.91)	5.4
Alestes minutus	46	5988.2	1- 4	1.51 (2.66)	14.1
Micralestes acutidens	1	0.1	4	+	+
Labeo horie	3	0.1	3-47	0.09 (0.46)	0.8
Barbus bynni	1	0.1	14-26	0.01 (0.05)	0.1
Engraulicypris stellae	8	2.6	1- 2	+	+
Schilbe uranoscopus	21	21.1	1-27	0.23 (0.49)	2.2
Bagrus bayad	7	0.7	7-37	0.14 (0.46)	1.3
Chrysichthys auratus	1	0.1	3	+	+
Synodontis schall	18	3.7	1-31	1.11 (3.83)	10.3
Lates longispinis	41	11.5	8-50	1.77 (2.32)	16.6
Lates niloticus	2	0.1	80-86	0.52 (2.67)	4.8
Lates post-larvae	15	11.7	1- 3	0.01 (0.05)	0.1
Haplochromis macconneli	3	0.8	3- 9	+	+
Sarotherodon niloticus	3	0.1	4-26	0.02 (0.08)	0.1
Macrobrachium niloticum	26	363.7	-	0.03 (0.09)	0.3
Caridina nilotica	1	0.5	-	+	+
TOTAL	54	6566.3		10.67	

TABLE 8.15

Showing mean catch per effort in both No/hr and kg/hr for 20 Boris midwater trawl hauls made in the midwater scattering layer situated at depths greater than 10 m. Otherwise as in Table 8.12

	No. of hauls present	No/hr	Size range (cm)	kg/hr(±SD)	% weight
Hydrocynus forskalii	13	7.3	13-62	2.46 (4.45)	38.3
Alestes baremose	3	0.3	26-31	0.07 (0.20)	1.1
Alestes ferox	16	62.5	2-11	0.33 (0.39)	5.2
Alestes minutus	15	1841.2	2- 4	0.52 (0.86)	8.1
Labeo horie	1	0.1	38	0.10 (0.44)	1.5
Barbus turkanae	1	0.2	3- 4	+	+
Engraulicypris stellae	2	4.6	2- 3	+	+
Schilbe uranoscopus	3	0.4	17-20	0.05 (0.16)	0.8
Bagrus bayad	1	0.1	36	0.06 (0.26)	0.9
Synodontis schall	2	0.2	2-23	0.04 (0.17)	0.6
Lates longispinis	15	7.1	8-54	1.94 (2.42)	30.3
Lates niloticus	1	0.1	86	0.78 (3.48)	12.1
Lates post-larvae	4	3.3	1- 2	+	+
Haplochromis macconneli	1	0.4	3- 5	+	+
Macrobrachium niloticum	6	290.0	-	0.05 (0.14)	0.7
Caridina nilotica	1	7.2	-	+	+
TOTAL	20	2225.0		6.40	

TABLE 8.16

A summary of data relating to vertical zonation in open water species from Boris midwater trawl hauls. Showing mean catch per effort in No/hr for each of 5 depth zones. The term 'deep layer' is used for the water column between the midwater scattering layer and the bottom.

	Hydrocynus forskalii	*Alestes baremose*	*Alestes minutus*	*Alestes ferox*	*Schilbe uranoscopus*	*Bagrus bayad*	*Synodontis schall*	*Lates longispinis*	*Haplochromis macconneli*	*Macrobrachium niloticum*	Number of hauls
Surface	5	2	158	4	-	-	-	1	-	-	16
Midwater scattering layer	17	1	5988	142	21	1	4	11	+	363	54
Upper deep layer	5	-	2159	46	20	-	3	3	-	392	5
Lower deep layer	3	-	771	18	4	8	1	3	-	442	5
Bottom	6	-	1932	83	2	120	4	6	165	139	1

TABLE 8.17

Summary of samples collected during frame trawl surveys

Period	Purpose of series	No. of hauls
September-December 1973	Vertical zonation depths < 30m	28
September-December 1973	Vertical zonation depths > 30m	17
April-May 1974	Vertical zonation depths 25-30m	52
July-August 1975	Correlation vertical zonation depths 25-30m with Triton data	34
April 1974	Diel changes in vertical zonation	36
July 1974 and September 1975	Lakewide horizontal distribution	62

TABLE 8.18

Comparing mean catch per effort (in gm/hr) for fish occurring in frame trawl hauls at lake depths of less than 30 m in the vicinity of Longech Spit for (a) tows made in midwater from the scattering layer downwards but excluding the bottom 3 metres and (b) tows made in the bottom 3 metres. Data for September-December 1973 and April-May 1974 have been combined

	Mean catch per effort (gm/hr)	
	Midwater	Bottom
Number of hauls	44	10
Schilbe uranoscopus	422.3	822.8
Bagrus bayad	281.9	3460.6
Chrysichthys auratus	8.1	52.4
Synodontis schall	2429.6	679.0
Lates longispinis	759.1	1781.0
Lates niloticus	4697.6	-
Haplochromis macconneli	1.7	59.4

TABLE 8.19

Summarising results from a total of 62 oblique frame trawl hauls from all areas of the lake, made during the months of July 1974 and September 1975

Species	Number stations recorded	Number/ standard haul	Weight (gms)/ standard haul ± SD	Size range (cm)	% weight	Areal density kg/km^2
Hydrocynus forskalii	9	0.2	11.2 (35.2)	5-30	5.4	143
Alestes baremose	8	0.1	1.3 (5.7)	6-22	0.6	16
Alestes ferox	39	3.7	7.6 (12.2)	1-10	3.6	97
Alestes minutus	41	13.3	4.9 (15.6)	1- 4	2.3	63
Alestes nurse	1	0.1	0.1	3- 5	+	1
Micralestes acutidens	7	0.3	0.2 (0.6)	3- 4	0.1	2
Labeo horie	3	+	0.1 (0.3)	3- 6	0.2	1
Barbus bynni	4	+	1.8 (10.1)	12-26	0.8	23
Barbus turkanae	28	1.3	1.0 (2.4)	2- 5	0.5	13
Engraulicypris stellae	13	0.8	0.1 (0.2)	1- 3	+	1
Schilbe uranoscopus	9	1.8	12.2 (37.3)	4-26	5.9	156
Chrysichthys autatus	8	1.0	1.5 (6.4)	2-14	0.7	19
Bagrus bayad	28	0.8	100.5 (240.4)	3-42	48.6	1282
Synodontis schall	11	1.3	20.7 (87.1)	2-30	10.0	264
Lates longispinis	15	0.4	22.0 (60.9)	2-35	10.6	281
Lates niloticus	1	+	13.1	45	6.3	167
Haplochromis macconneli	27	2.5	8.6 (19.7)	2-10	4.1	109
		27.6	206.9			2638

TABLE 8.20

Estimated biomass (in tonnes) of fish occurring in Lake Turkana below the 5 metre contour, a total area of 6750 km^2. The values are based on areal densities derived from an oblique frame trawl survey (Table 8.19). Sampling was carried out during the flood season in July 1974 and September 1975

Species	Estimated biomass (tonnes)
Hydrocynus forskalii	965
Alestes baremose	109
Alestes ferox	653
Alestes minutus	426
Barbus bynni	156
Barbus turkanae	86
Schilbe uranoscopus	1053
Chrysichthys auratus	130
Bagrus bayad	8657
Synodontis schall	1783
Lates longispinis	1897
Lates niloticus	1127*
Haplochromis macconneli	739
Others	31
TOTAL	17,806

*based on a single fish

TABLE 8.21

Summary of samples collected during metre townet surveys

Period	Purpose of series	Number of hauls
February 1975	Vertical zonation Longech Spit area	21
February 1975	Vertical zonation on east west lake transect	35
November 1975	Diel changes in vertical zonation	14
1972-1975	Horizontal distribution June-July	68
1972-1975	Horizontal distribution August-October	74
1972-1975	Horizontal distribution November-May	71

TABLE 8.22

Showing biomass in tonnes estimated for the principal species occurring in oblique metre townet hauls by sector and by depth.

Depth zone(m)	Area (km^2)	No hauls	Alestes minutus	Engraulicypris stellae	Lates post-larvae	Macrobrachium niloticum	Caridina nilotica	Other fish	Total
Northern Sector									
0-10	1049	32	2863	299	86	487	5	1874	5614
10-20	564	23	5572	457	56	433	34	578	7130
20-30	472	13	1106	1432	17	462	25	215	3257
30-40	181	3	93	33	2	64	6	29	227
40-50	23	3	9	3	1	22	+	16	51
Total Northern Sector	2289	74	9643	2224	162	1468	70	2712	16279
Central Sector									
0-10	478	4	8	1969	8	6	15	0	2006
10-20	488	18	144	211	6	757	65	14	1197
20-30	614	12	1055	1532	105	491	21	16	3220
30-40	578	9	454	2131	10	669	104	2	3370
40-50	441	7	88	2467	8	183	11	13	2770
50-60	442	8	30	637	3	307	13	14	1004
60-70	331	6	16	422	5	519	54	75	1091
70-80	203	14	49	413	+	215	42	3	722
80 +	127	18	21	331	2	99	30	19	502
Total Central Sector	3702	96	1865	10113	147	3246	355	156	15882
Southern Sector									
0-10	92	0	-	-	-	-	-	-	
10-20	148	2	0	5	+	1	9	0	15
20-30	183	9	5	183	3	3	2	0	196
30-40	247	7	13	47	2	38	18	35	153
40-50	234	8	16	73	2	13	21	27	152
50-60	367	6	0	511	1	175	15	14	716
60-70	198	10	2	415	1	15	19	0	452
70-80	67	2	0	24	+	122	5	191	342
80 +	34	5	+	11	1	53	2	25	92
Total Southern Sector	1570	49	36	1269	10	419	91	293	2118
Lakewide Total	7561	219	11544	13606	319	5133	516	3161	34729

TABLE 8.23

The results of a survey with midwater gillnets carried out in open water off Longech Spit during August and September 1974. Showing catch per effort in kg/100m headrope/night for each species in nets of 4.3 inch stretched mesh set at different depths at each of five stations.

Station	A		B			C			
Lake depth (m)	10		16			22			
Position of net (headrope depth)	Surface	Bottom	Surface	5.5m	Bottom	Surface	5.5m	11m	Bottom
Number of nights	1	1	1	1	1	1	1	1	1
Total nets set	1	1	1	1	1	1	1	1	1
Hydrocynus forskalii	-	0.6	0.9	-	1.1	-	-	-	-
Distichodus niloticus	-	2.3	-	-	2.3	4.4	3.2	2.0	-
Labeo horie	-	-	-	-	-	10.2	-	4.6	-
Barbus bynni	-	4.8	-	1.3	1.8	1.1	-	4.1	-
Schilbe uranoscopus	-	0.9	-	-	0.4	-	0.2	-	0.2
Synodontis schall	81.7	18.8	36.7	25.6	26.5	26.0	13.9	13.0	3.2
Lates longispinis	2.3	6.2	-	1.6	8.6	3.2	-	-	11.8
Total	84.0	33.9	37.7	28.6	40.9	45.1	17.4	23.9	15.3

contd./

TABLE 8.23 (contd.) Sheet 2

Station D (Lake depth 27m)

Position of net (headrope depth)	Surface	5m	11m	16m	Bottom
Number of nights	5	5	6	6	7
Total nets set	7	6	8	8	11
Hydrocynus forskalii	3.9	3.8	3.0	2.0	0.6
Distichodus niloticus	0.3	0.5	0.6	-	0.1
Labeo horie	1.6	4.6	5.7	2.2	1.4
Barbus bynni	0.7	1.4	5.7	4.3	5.0
Schilbe uranoscopus	-	0.1	+	+	-
Bagrus bayad	0.6	-	-	0.6	0.6
Chrysichthys auratus	-	-	+	-	-
Synodontis schall	56.9	29.9	19.1	21.7	8.3
Lates niloticus	3.0	-	1.3	-	1.0
Lates longispinis	1.4	3.4	7.4	6.0	4.2
Total	68.9	43.9	43.0	37.2	21.5

contd./

TABLE 8.23 (contd.) Sheet 3

Station E (Lake depth 50m)

Position of net (Headrope depth)	5m	11m	16m	20m	26m	32m	37.5m	Bottom
Number of nights	2	5	5	5	4	2	2	2
Total nets set	2	5	5	5	4	2	2	2
Hydrocynus forskalii	88.8	0.8	0.6	-	2.9	-	-	-
Alestes baremose	2.3	0.3	-	-	-	-	-	-
Barbus bynni	-	0.4	0.2	0.6	10.3	3.8	6.5	-
Schilbe uranoscopus	-	-	+	0.1	-	-	-	-
Bagrus bayad	-	-	-	-	-	-	-	6.2
Chrysichthys auratus	-	-	+	-	-	-	-	-
Synodontis schall	2.5	7.3	2.5	7.1	5.2	-	-	7.7
Lates niloticus	-	-	-	3.5	-	-	-	53.0
Lates longispinis	-	3.1	2.7	1.1	0.2	0.3	1.6	2.2
Sarotherodon niloticus	0.2	-	-	-	-	-	-	-
Total	13.9	12.0	6.2	12.5	18.9	4.2	8.1	69.3

TABLE 8.24

The result of a survey with a graded fleet of bottom set gillnets carried out on a transect running east from Longech Spit during February-June 1974. The four stations have been selected for their position relative to the midwater scattering layer which impinged on the bottom between the 13 and 19m contours. Catch per effort is expressed in kg/100m headrope/night for each species together with the % of total catch by weight in brackets.

Station A : Lake depth 9m - above scattering layer

Stretched mesh size (inches)	2	3	4	5	6	7	8	9	10
No. nights	4	4	4	4	4	4	4	4	4
Hydrocynus forskalii	3.8 (23)	14.0 (20)	0.7 (2)	1.1 (2)	-	-	-	-	-
Alestes baremose	1.1 (7)	-	-	-	-	-	-	-	-
Citharinus citharus	-	-	-	1.9 (4)	1.4 (5)	1.6 (20)	9.9 (65)	2.7 (18)	-
Distichodus niloticus	-	1.9 (3)	2.7 (7)	1.6 (3)	0.8 (3)	1.3 (16)	1.1 (7)	-	-
Labeo horie	1.2 (7)	12.9 (19)	25.0 (62)	30.2 (69)	22.2 (81)	5.2 (62)	-	-	-
Barbus bynni	0.4 (2)	8.5 (12)	6.8 (17)	3.8 (9)	-	-	-	-	-
Schilbe uranoscopus	5.5 (34)	18.1 (26)	-	-	-	-	-	-	-
Bagrus bayad	-	0.2 (+)	0.5 (1)	-	-	-	-	-	-
Bagrus docmac	-	-	-	0.5 (1)	-	-	-	-	-
Chrysichthys auratus	0.1 (+)	+ (+)	-	-	-	-	-	-	-
Synodontis schall	3.3 (20)	9.0 (13)	3.0 (7)	0.3 (1)	0.3 (1)	0.1 (2)	0.1 (1)	0.1 (1)	-
Lates niloticus	-	1.9 (3)	0.2 (+)	4.4 (10)	2.7 (10)	-	4.1 (27)	12.2 (81)	-
Lates longispinis	0.8 (5)	2.4 (3)	1.6 (4)	-	-	-	-	-	-
Sarotherodon niloticus	-	-	-	-	-	-	-	-	-
Total	16.2	68.9	40.5	43.8	27.5	8.4	15.2	15.1	0

contd.

TABLE 8.24 (contd.) Sheet 2

Station B : Lake depth 14m - upper fringe of scattering layer

Stretched mesh size (inches)	2	3	4	5	6	7	8	9	10
No. nights	6	6	5	5	5	6	6	6	6
Hydrocynus forskalii	15.9 (44)	12.7 (14)	1.7 (3)	0.4 (1)	1.9 (8)	-	-	-	-
Alestes baremose	0.3 (1)	0.3 (+)	0.2 (+)	-	-	-	-	-	-
Citharinus citharus	-	-	-	-	-	-	-	-	-
Distichodus niloticus	-	0.9 (1)	4.1 (8)	1.7 (5)	1.1 (5)	0.7 (42)	-	1.1 (24)	-
Labeo horie	4.5 (12)	33.9 (36)	22.8 (45)	30.3 (82)	18.9 (81)	0.9 (52)	-	-	-
Barbus bynni	3.6 (10)	20.4 (22)	15.6 (31)	3.7 (10)	1.1 (5)	-	-	-	-
Schilbe uranoscopus	5.9 (16)	8.2 (9)	-	-	-	-	-	-	-
Bagrus bayad	1.1 (3)	0.9 (1)	0.8 (2)	-	-	-	-	-	1.1 (19)
Bagrus docmac	-	0.3 (+)	-	-	-	-	-	-	-
Chrysichthys auratus	+ (+)	+ (+)	-	-	-	-	-	-	-
Synodontis schall	3.0 (8)	9.7 (10)	4.6 (9)	0.2 (+)	0.1 (+)	0.1 (5)	-	0.1 (2)	-
Lates niloticus	0.3 (1)	0.3 (+)	0.4 (1)	0.4 (1)	-	-	-	3.3 (73)	4.7 (81)
Lates longispinis	1.1 (3)	6.3 (7)	0.4 (1)	0.1 (+)	-	-	-	-	-
Sarotherodon niloticus	0.5 (1)	-	0.2 (+)	-	-	-	-	-	-
Total	36.2	94.4	51.3	37.1	23.2	1.7	0	5.0	5.9

contd.

TABLE 8.24 (contd.) Sheet 3

Station C : Lake depth 19m - within scattering layer

Stretched mesh size (inches)	2	3	4	5	6	7	8	9	10
No. nights	7	7	7	7	7	7	7	7	7
Hydrocynus forskalii	6.6 (14)	5.9 (8)	3.4 (7)	3.4 (20)	-	-	-	-	-
Alestes baremose	+ (+)	-	-	-	-	-	-	-	-
Citharinus citharus	-	-	-	-	-	-	-	-	-
Distichodus niloticus	-	-	0.1 (+)	-	-	-	-	-	-
Labeo horie	0.8 (2)	2.2 (3)	3.1 (7)	5.9 (34)	1.2 (24)	-	-	-	-
Barbus bynni	4.9 (10)	14.6 (19)	14.9 (32)	5.8 (33)	1.2 (24)	-	-	-	-
Schilbe uranoscopus	1.4 (3)	1.4 (2)	+ (+)	-	-	-	-	-	-
Bagrus bayad	0.3 (1)	0.9 (1)	3.7 (8)	1.2 (7)	3.5 (69)	-	0.9 (80)	-	-
Bagrus docmac	-	-	-	-	-	-	-	-	-
Chrysichthys auratus	0.1 (+)	+ (+)	-	-	-	-	-	-	-
Synodontis schall	19.9 (43)	36.3 (46)	18.3 (39)	1.0 (6)	0.1 (3)	0.3 (29)	0.2 (20)	-	-
Lates niloticus	-	1.7 (2)	0.6 (1)	0.6 (3)	-	0.9 (69)	-	-	-
Lates longispinis	11.6 (25)	14.6 (18)	2.2 (5)	0.4 (2)	0.1 (3)	+ (2)	-	-	-
Sarotherodon niloticus	-	-	-	-	-	-	-	-	-
Total	46.0	77.8	46.7	18.5	6.4	1.4	1.2		

contd./

TABLE 8.24 (contd.) Sheet 4

Station D : Lake depth 25m - below scattering layer

Stretched mesh size (inches)	2	3	4	5	6	7	8	9	10
No. nights	4	4	4	4	4	4	4	4	4
Hydrocynus forskalii	0.2 (1)	-	-	-	-	-	-	-	-
Alestes baremose	-	-	-	-	-	-	-	-	-
Citharinus citharus	-	-	-	-	-	-	-	-	-
Distichodus niloticus	-	-	-	-	-	-	-	-	-
Labeo horie	0.2 (1)	0.2 (1)	0.5 (1)	1.1 (14)	-	-	-	-	-
Barbus bynni	0.8 (2)	4.1 (11)	8.1 (24)	4.1 (54)	0.5 (14)	-	-	-	-
Schilbe uranoscopus	3.4 (9)	8.3 (23)	+ (+)	-	-	-	-	-	-
Bagrus bayad	-	1.6 (4)	3.8 (11)	1.1 (14)	2.7 (69)	3.0 (22)	3.3 (92)	-	1.6 (8)
Bagrus docmac	-	-	-	-	-	-	-	-	-
Chrysichthys auratus	-	-	-	-	-	-	-	-	-
Synodontis schall	22.2 (60)	12.9 (36)	17.7 (52)	1.2 (16)	0.4 (10)	0.1 (1)	-	-	0.1 (+)
Lates niloticus	-	1.9 (5)	-	-	-	10.5 (77)	-	5.0(100)	18.1 (90)
Lates longispinis	10.1 (27)	6.8 (19)	3.7 (11)	0.1 (2)	0.2 (7)	-	0.2 (7)	-	-
Sarotherodon niloticus	-	-	-	-	-	-	-	-	-
Total	37.2	36.2	34.0	7.7	4.0	13.8	3.6	5.0	19.9

TABLE 8.25 a-r

Showing the results of a survey with fine mesh surface set gillnets fished at a total of 18 stations situated in all sectors of the lake during the period May 1974-August 1975. Catch per effort is expressed as kg/100 m headrope/night for each species with the percentage by weight of total catch in brackets

a) Dielerheile (Omo Delta) grid ref. HBH 390930
Distance offshore 2 km Lake depth 4 m

Stretched mesh size	2½	3	3½	4
Number of nights	1	1	3	3
Hyperopisus bebe	-	-	-	0.7 (1)
Hydrocynus forskalii	1.1 (41)	7.6 (25)	0.3 (+)	3.2 (4)
Alestes baremose	1.5 (58)	4.5 (15)	37.5 (88)	10.5 (14)
Barbus bynni	-	8.7 (28)	0.7 (1)	5.4 (+)
Schilbe uranoscopus	-	3.2 (11)	1.0 (1)	0.5 (+)
Bagrus bayad	-	-	0.3 (+)	3.6 (5)
Synodontis schall	-	6.5 (21)	53.9 (55)	47.4 (63)
Lates niloticus	-	-	4.3 (4)	3.2 (4)
TOTAL	2.6	30.5	98.0	74.5

b) Ilaret grid ref. HBH 540810
Distance offshore 1 km Lake depth 6 m

Stretched mesh size (inches)	2½	3	3½
Number of nights	14	13	14
Hydrocynus forskalii	12.5 (21)	10.5 (18)	4.8 (8)
Alestes baremose	36.1 (61)	32.2 (56)	23.7 (38)
Citharinus citharus	0.5 (1)	2.2 (4)	0.8 (1)
Labeo horie	0.2 (+)	1.2 (2)	2.8 (5)
Barbus bynni	1.8 (3)	3.1 (5)	12.8 (21)
Schilbe uranoscopus	2.8 (5)	0.8 (1)	+ (+)
Bagrus bayad	+ (+)	- -	- -
Chrysichtys auratus	+ (+)	- -	- -
Synodontis schall	1.4 (2)	2.9 (5)	5.4 (9)
Lates niloticus	1.5 (2)	4.0 (7)	6.6 (11)
Lates longispinis	1.8 (3)	0.6 (1)	3.3 (5)
Mean total nightly catch	58.7	57.4	61.5

c) Kakoi grid ref.
Distance offshore 400 m Lake depth 12 m

Stretched mesh size (inches)	2	2½	3	3½
Number of nights	1	1	1	1
Hydrocynus forskalii	6.6 (6)	2.6 (3)	2.3 (3)	3.7 (6)
Alestes baremose	98.2 (92)	86.9 (97)	70.2 (94)	62.0 (94)
Labeo horie	0.4 (+)	-	-	-
Barbus bynni	1.5 (1)	-	2.2 (3)	-
Mean total nightly catch	106.8	89.5	74.6	66.0

d) North Island grid ref. HBH 370490
Distance offshore 600 m Lake depth 20 m

Stretched mesh size (inches)	2½	3	3½
Number of nights	1	1	1
Hydrocynus forskalii	21.8 (15)	13.1 (11)	-
Alestes baremose	123.6 (85)	100.6 (87)	97.4 (82)
Schilbe uranoscopus	-	2.2 (2)	-
Lates niloticus	-	-	21.8 (18)
Mean total nightly catch	145.4	115.9	119.2

e) Koobi Fora grid ref. HBH 530370
Distance offshore 800 m Lake depth 6 m

Stretched mesh size (inches)	2½	3	3½
Number of nights	14	13	13
Hydrocynus forskalii	7.2 (9)	5.6 (7)	2.6 (4)
Alestes baremose	70.4 (89)	69.7 (85)	40.2 (68)
Alestes dentex	0.1 (+)	-	1.5 (2)
Citharinus citharus	-	0.1 (+)	0.9 (1)
Labeo horie	0.2 (+)	0.7 (1)	-
Barbus bynni	0.1 (+)	0.7 (1)	1.3 (2)
Schilbe uranoscopus	0.8 (1)	0.5 (+)	0.7 (1)
Bagrus bayad	0.1 (+)	-	-
Synodontis schall	0.1 (+)	0.2 (+)	0.7 (1)
Lates niloticus	-	4.2 (5)	10.7 (18)
Sarotherodon galilaeus	+ (+)	-	-
Mean total nightly catch	79.2	81.8	58.8

f) Allia Bay grid ref. HBH 590090
Distance offshore 1 km Lake depth 6 m

Stretched mesh size (inches)	2½	3	3½
Number of nights	19	18	17
Hydrocynus forskalii	32.8 (66)	25.5 (50)	15. 7 (31)
Alestes baremose	11.6 (23)	11.2 (22)	8.0 (16)
Alestes dentex	1.1 (2)	2.3 (5)	1.8 (4)
Citharinus citharus	0.2 (+)	0.5 (1)	1.1 (2)
Distichodus niloticus	+ (+)	-	-
Labeo horie	0.7 (1)	1.3 (2)	7.7 (15)
Barbus bynni	0.5 (1)	1.9 (4)	2.6 (5)
Schilbe uranoscopus	0.2 (+)	0.3 (+)	-
Bagrus bayad	-	0.6 (1)	1.3 (3)
Synodontis schall	1.1 (2)	2.3 (4)	5.2 (10)
Lates niloticus	1.3 (2)	4.2 (8)	6.1 (12)
Lates longispinis	-	-	0.1 (+)
Mean total nightly catch	49.9	50.4	49.8

g) Kataboi grid ref. HBH 170150
Distance offshore 1 km Lake depth 10 m

Stretched mesh size (inches)	2½	3	3½	4
Number of nights	4	4	4	4
Hydrocynus forskalii	4.1 (10)	1.1 (3)	0.6 (3)	2.7 (16)
Alestes baremose	28.9 (75)	30.1 (78)	12.3 (58)	-
Distichodus niloticus	-	-	-	0.5 (3)
Labeo horie	0.4 (1)	0.5 (1)	-	2.6 (15)
Barbus bynni	-	1.5 (4)	0.4 (2)	-
Schilbe uranoscopus	2.0 (5)	0.2 (+)	-	-
Synodontis schall	0.4 (1)	4.9 (12)	7.8 (37)	10.0 (60)
Lates niloticus	2.8 (7)	0.4 (1)	-	0.5 (3)
Mean nightly catch	38.6	38.7	21.1	16.7

h) Nayanaalupuyei grid ref. HBH 160080
Distance offshore 1 km Lake depth 10 m

Stretched mesh size (inches)	2½	3	3½	4
Number of nights	4	4	4	4
Hydrocynus forskalii	6.0 (13)	1.7 (3)	-	2.3 (3)
Alestes baremose	23.9 (52)	28.8 (49)	5.0 (11)	-
Labeo horie	1.9 (4)	2.2 (4)	0.4 (1)	-
Barbus bynni	-	0.7 (1)	0.2 (+)	-
Schilbe uranoscopus	1.8 (4)	0.6 (1)	-	-
Synodontis schall	11.8 (26)	24.0 (41)	40.8 (86)	63.9 (96)
Lates niloticus	-	0.5 (1)	-	-
Sarotherodon niloticus	-	-	0.3 (+)	-
Sarotherodon galilaeus	-	-	0.2 (+)	-
Mean total nightly catch	45.5	58.5	47.1	66.2

i) Namadak grid ref. HBB 160990
Distance offshore 1 km Lake depth 10 m

Stretched mesh size (inches)	2½	3	3½	4
Number of nights	4	4	4	4
Hydrocynus forskalii	11.2 (23)	2.9 (5)	-	-
Alestes baremose	31.5 (64)	42.2 (78)	12.4 (35)	0.8 (2)
Labeo horie	-	-	-	1.1 (3)
Barbus bynni	-	-	-	0.6 (2)
Schilbe uranoscopus	0.7 (1)	0.3 (+)	-	-
Synodontis schall	5.7 (12)	8.9 (16)	23.3 (65)	29.7 (92)
Mean total nightly catch	49.2	54.3	35.7	32.3

j) Longech Spit Grid ref : HBB 250940

Distance offshore : 800m. Lake depth 8-10m.

Stretched mesh size (inches)	2	2½	3	3½	4
Number of nights	15	12	14	10	4
Hydrocynus forskalii	20.3 (27)	21.0 (43)	13.5 (30)	2.5 (8)	5.3 (12)
Alestes baremose	47.9 (63)	19.3 (40)	22.3 (50)	11.1 (37)	0.1 (+)
Distichodus niloticus	-	-	-	0.1 (+)	-
Labeo horie	0.6 (1)	2.0 (4)	2.5 (5)	8.5 (28)	18.5 (44)
Barbus bynni	0.1 (+)	0.1 (+)	0.1 (+)	0.7 (2)	1.3 (3)
Schilbe uranoscopus	0.7 (1)	0.5 (1)	0.1 (+)	-	-
Synodontis schall	6.5 (8)	3.0 (6)	6.1 (14)	6.7 (22)	16.7 (40)
Lates niloticus	0.1 (+)	2.7 (6)	-	0.1 (+)	-
Lates longispinis	0.1 (+)	-	0.2 (+)	0.3 (1)	-
Mean total nightly catch	76.4	48.6	44.8	29.7	41.9

k) Ferguson's Gulf grid ref. HBB 250880
Distance offshore 200-600 m Lake depth 1.5-2 m

Stretched mesh size (inches)	3	3½	4
Number of nights	5	5	5
Hydrocynus forskalii	0.8 (1)	0.4 (2)	-
Alestes baremose	1.1 (1)	-	-
Labeo horie	66.9 (70)	1.1 (6)	-
Barbus bynni	2.3 (2)	1.2 (7)	0.8 (3)
Clarias lazera	0.9 (1)	-	3.2 (11)
Schilbe uranoscopus	5.6 (6)	-	-
Bagrus bayad	1.7 (2)	0.9 (5)	2.8 (9)
Synodontis schall	8.1 (8)	4.2 (23)	3.0 (10)
Lates niloticus	2.8 (3)	0.4 (2)	0.8 (3)
Sarotherodon niloticus	4.9 (5)	10.1 (55)	19.1 (64)
Sarotherodon galilaeus	0.1 (+)	-	-
Mean total nightly catch	95.3	18.2	30.0

l) Central Island grid ref. HBB 380870
Distance offshore 800 m Lake depth 40-50 m

Stretched mesh size (inches)	2	2½	3	3½
Number of nights	3	7	6	2
Hydrocynus forskalii	12.7 (32)	11.2 (39)	4.8 (12)	1.1 (92)
Alestes baremose	23.7 (60)	15.5 (53)	23.9 (60)	47.2 (71)
Alestes dentex	-	1.0 (3)	9.4 (24)	-
Labeo horie	-	+ (+)	0.5 (1)	5.4 (8)
Barbus bynni	-	0.1 (+)	-	-
Schilbe uranoscopus	+ (+)	0.1 (+)	0.2 (+)	-
Synodontis schall	2.9 (7)	0.4 (2)	0.7 (2)	12.6 (19)
Lates longispinis	-	0.3 (1)	-	-
Mean total nightly catch	39.4	29.0	39.7	66.4

m) Open waters between Longech Spit and Allia Bay

Distance offshore : up to 15 km Lake depth up to 80m.

Stretched mesh size (inches)	2	2½	3	3½	4
Number of nights	4	7	3	3	5
Hydrocynus forskalii	35.8 (50)	20.6 (60)	3.5 (15)	0.7 (6)	1.3 (10)
Alestes baromose	5.2 (7)	11.6 (34)	15.8 (70)	11.3 (94)	2.6 (20)
Alestes dentex	-	-	0.4 (2)	-	-
Schilbe uranoscopus	-	1.2 (3)	-	-	-
Synodontis schall	29.2 (40)	0.7 (2)	-	-	8.6 (69)
Lates niloticus	-	-	2.7 (12)	-	-
Lates longispinis	1.7 (2)	-	0.3 (1)	-	-
Mean total nightly catch	72.0	34.1	22.7	12.0	12.6

n) Moite grid ref. HBB 600700
Distance offshore 600 m Lake depth 6 m

Stretched mesh size (inches)	2½	3	3½
Number of nights	8	7	7
Hydrocynus forskalii	26.7 (47)	16.9 (44)	4.6 (21)
Alestes baremose	29.9 (52)	21.0 (55)	13.2 (60)
Alestes dentex	-	+ (+)	-
Labeo horie	-	-	0.2 (1)
Barbus bynni	-	-	1.5 (6)
Schilbe uranoscopus	0.3 (1)	-	-
Synodontis schall	-	+ (+)	+ (+)
Lates niloticus	-	-	2.1 (10)
Mean total nightly catch	57.0	38.2	21.8

o) Otus grid ref.
Distance offshore 600 m Lake depth 10 m

Stretched mesh size (inches)	2½	3	3½
Number of nights	1	1	1
Hydrocynus forskalii	1.7 (22)	21.8 (73)	-
Alestes baremose	61. (77)	8.0 (27)	2.8 (29)
Alestes dentex	-	-	3.7 (38)
Labeo horie	-	-	3.3 (33)
Mean total nightly catch	7.8	29.9	9.8

p) Sandy Bay grid ref. HBB 770350
distance offshore 300 m Lake depth 3 m

Stretched mesh size (inches)	2½	3	3½
Number of nights	7	7	7
Hydrocynus forskalii	14.3 (38)	8.0 (36)	7.5 (42)
Alestes baremose	17.2 (46)	5.5 (25)	2.8 (16)
Alestes dentex	1.4 (3)	2.8 (13)	0.6 (3)
Labeo horie	2.2 (6)	2.4 (11)	3.8 (21)
Barbus bynni	0.1 (+)	0.2 (1)	0.6 (3)
Schilbe uranoscopus	0.1 (+)	0.2 (1)	0.1 (+)
Bagrus bayad	0.2 (+)	-	-
Chrysichthys auratus	0.7 (2)	0.2 (1)	0.1 (+)
Synodontis schall	0.6 (2)	1.0 (4)	1.2 (7)
Lates niloticus	0.6 (2)	1.6 (7)	0.9 (5)
Lates longispinis	-	-	0.1 (+)
Sarotherodon niloticus	-	-	0.6 (3)
Sarotherodon galilaeus	-	0.1 (+)	0.2 (1)
Mean total nightly catch	37.4	22.0	17.6

q) El Molo Bay grid ref. HBC 100130
Distance offshore 500 m Lake depth 5 m

Stretched mesh size (inches)	2½	3	3½
Number of nights	9	9	9
Hydrocynus forskalii	7.1 (24)	7.7 (22)	7.8 (26)
Alestes baremose	19.1 (64)	15.1 (44)	4.7 (16)
Alestes dentex	1.9 (7)	4.5 (13)	2.3 (8)
Labeo horie	0.7 (2)	5.4 (16)	5.4 (18)
Barbus bynni	-	0.7 (2)	1.3 (4)
Schilbe uranoscopus	-	0.1 (+)	+ (+)
Synodontis schall	-	0.2 (+)	0.3 (1)
Lates niloticus	0.8 (2)	0.1 (+)	7.6 (26)
Mean total nightly catch	29.8	34.3	29.7

r) South Island grid ref. HAP 970920
Distance offshore 500 m Lake depth 20 m

Stretched mesh size (inches)	2½	3	3½
Number of nights	3	3	3
Hydrocynus forskalii	3.6 (10)	5.5 (26)	1.4 (10)
Alestes baremose	15.1 (42)	13.8 (65)	11.7 (86)
Alestes dentex	-	1.8 (8)	0.4 (3)
Lates niloticus	17.2 (48)	-	-
Mean total nightly catch	35.9	21.1	13.5

TABLE 8.26 a - h

Showing catch per effort in kg/100m headrope for coarse mesh surface set gillnets fished at seven stations during the period June 1974-August 1975. The percentage by weight of total catch for a particular net is given for each species in brackets. Supplementary information relating to 6 inch gillnets in the Loiengalani area is appended.

a) Dielerheile (Omo delta)

Stretched mesh size (inches)	5	6	7	8
No. nights	3	3	3	3
Hydrocynus forskalii	7.6 (28)	18.4 (38)	-	-
Citharinus citharus	-	-	1.8 (7)	1.6 (2)
Labeo horie	1.1 (4)	-	-	-
Barbus bynni	11.6 (42)	9.8 (20)	2.2 (9)	-
Bagrus bayad	-	2.9 (6)	-	-
Synodontis schall	1.1 (4)	0.3 (1)	0.5 (2)	0.2 (+)
Lates niloticus	5.4 (20)	16.6 (34)	18.9 (81)	82.5 (98)
Total	26.8	48.0	23.4	84.3

b) Ilaret

Stretched mesh size (inches)	5	6	7	8
No. nights	3	4	2	3
Hydrocynus forskalii	4.7 (8)	2.1 (9)	-	-
Citharinus citharus	13.8 (24)	10.9 (48)	16.4 (79)	22.6 (77)
Labeo horie	14.5 (26)	-	-	-
Barbus bynni	21.1 (37)	3.2 (14)	4.3 (21)	1.4 (5)
Schilbe uranoscopus	0.1 (+)	-	-	-
Bagrus bayad	0.7 (1)	1.4 (6)	-	-
Synodontis schall	1.2 (2)	0.6 (3)	-	-
Lates niloticus	-	4.1 (18)	-	5.1 (17)
Total	56.1	22.3	20.7	29.1

contd./

TABLE 8.26 (contd.) Sheet 2

c) Koobi Fora

Stretched mesh size (inches)	5	6	7	8
No. nights	3	1	2	2
Hydrocynus forskalii	4.3 (13)	-	-	-
Labeo horie	27.3 (83)	-	-	-
Synodontis schall	1.3 (4)	-	-	-
Lates niloticus	-	7.6(100)	35.0(100)	33.3(100)
Total	33.9	7.6	35.0	33.3

d) Allia Bay

Stretched mesh size (inches)	5	6	7	8
No. nights	7	7	6	5
Hydrocynus forskalii	7.7 (31)	1.0 (7)	-	-
Citharinus citharus	0.2 (1)	0.9 (7)	0.7 (3)	6.0 (7)
Distichodus niloticus	0.5 (2)	0.7 (6)	-	-
Labeo horie	7.3 (30)	3.7 (27)	-	-
Barbus bynni	0.4 (1)	1.0 (8)	-	-
Synodontis schall	1.6 (7)	-	-	-
Lates niloticus	6.5 (27)	6.3 (45)	20.6 (97)	73.6 (92)
Total	24.2	13.6	21.3	79.6

e) Moite

Stretched mesh size (inches)	5	6	7	8
No. nights	5	3	3	3
Hydrocynus forskalii	0.6 (41)	-	-	-
Barbus bynni	0.9 (58)	-	-	-
Lates niloticus	-	-	6.5(100)	5.4(100)
Total	1.5	0	6.5	5.4

contd./

TABLE 8.26 (contd.) Sheet 3

f) Sandy Bay

Stretched mesh size (inches)	5	6	7	8
No. nights	3	2	2	2
Hydrocynus forskalii	1.1 (16)	3.2(100)	-	-
Citharinus citharus	-	-	-	2.7 (31)
Labeo horie	3.4 (53)	-	-	-
Barbus bynni	1.4 (21)	-	-	-
Bagrus bayad	0.1 (2)	-	-	-
Synodontis schall	0.5 (8)	-	-	-
Lates niloticus	-	-	-	6.0 (68)
Total	6.5	3.2	0	8.7

g) El Molo Bay

Stretched mesh size (inches)	5	6	7	8
No. nights	3	2	2	2
Barbus bynni	5.1 (41)	-	-	6.5(100)
Bagrus docmac	5.4 (44)	-	-	-
Synodontis schall	0.3 (3)	-	-	-
Lates niloticus	1.4 (12)	11.4(100)	-	-
Total	12.2	11.4	0	6.5

contd./

TABLE 8.26 (contd.) Sheet 4

h) Supplementary results.

The following data were collected by members of the Italian Volunteer Corps during February-May 1975 using 6 inch surface set gillnets provided by the project. Mean catch per effort is expressed in kg/100m headrope/night, and the percentage by weight of total catch is shown in brackets for each species.

	Elavto Island	El Molo Bay	Loiengalani Bay	Soit Nabor	Sirima
No. of nights	10	4	24	2	5
Citharinus citharus	0.3 (+)	-	0.1 (+)	-	-
Distichodus niloticus	-	-	0.2 (+)	-	-
Labeo horie	34.5 (57)	6.3 (12)	25.3 (34)	12.6 (20)	4.4 (13)
Barbus bynni	7.7 (13)	11.5 (23)	3.4 (4)	-	-
Bagrus bayad	2.2 (4)	-	1.2 (2)	-	-
Bagrus docmac	2.5 (4)	9.2 (18)	3.6 (5)	-	1.8 (5)
Clarias lazera	-	-	0.2 (+)	-	-
Synodontis schall	2.9 (5)	0.4 (1)	1.0 (1)	-	-
Lates niloticus	8.4 (14)	28.7 (58)	38.1 (51)	43.8 (70)	27.2 (81)
Sarotherodon niloticus	2.6 (4)	-	1.7 (2)	6.0 (10)	-
Sarotherodon galilaeus	-	-	0.2 (+)	-	-
Total	61.1	56.1	75.0	62.4	33.4

TABLE 8.27

Acoustic biomass estimates of the demersal population and midwater scattering layer in Lake Turkana in water > 10 m deep

Survey date	6-29.6.74	10-28.9.74	11-30.11.74	9-29.6.75
Area covered km^2	6310	6370	6425	6255
Absolute biomass demersal population (tonnes)	-	13595	12867	12946
Relative biomass demersal population	-	1210	1028	1126
Relative biomass midwater scattering layer	20892	-	11114	24048
Relative biomass south of Nov. 1974 10 m scattering layer depth contour	14308	-	10757	13559

TABLE 8.28

Acoustic standing stock estimates of the major species taken by bottom trawl in Lake Turkana at depths > 10 m

Species	September 1974 tonnes	September 1974 %	November 1974 tonnes	November 1974 %	June 1975 tonnes	June 1975 %
Labeo horie	172	1.3	102	0.8	90	0.7
Barbus bynni	937	7	251	2	743	7
Schilbe uranoscopus	156	1.2	188	1.5	533	4
Bagrus bayad	6363	48	6548	52	4684	37
Chrysichthys auratus	111	0.8	15	0.1	124	1
Synodontis schall	1470	11	1211	10	1352	11
Lates longispinis	1394	10	2212	18	2100	17
Lates niloticus	2733	20	2001	16	2998	24
Haplochromis macconneli	42	0.3	70	0.6	85	0.7
TOTAL	13378		12598		12709	

TABLE 8.29

	June 1974		November 1974	June 1975	
	Total survey area	Area of Nov. 1974 survey	Areas of lake where scattering layer deeper than 10m	Total survey area	Area of Nov. 1974 survey
Area covered km^2	6310	4703	4703	6255	4703
Relative biomass	20892	14308	10757	13559	24048
Absolute biomass (tonnes)	245481		126394		282564
Biomass per unit area	38.9	35.7	26.9	45.2	33.9

TABLE 8.30

Summarising estimates of areal density (in kg/km^2) for various species of openwater fish obtained during the present investigations. (MWSL = midwater scattering layer) - (* = post-larvae of *Lates* spp.)

Column number	1	2	3	4	5	6	7
Survey method	Bottom trawl (c_v=1)	Bottom trawl (c_v=1)	Acoustic	Bottom trawl (c_v-corrected)	Frame trawl	Acoustic	Metre townet
Stretched mesh size	38mm	38mm	-	38mm	19mm	-	0.8mm
Depth layers sampled	Bottom 4m	Bottom 4m	Bottom 4m	MWSL to bottom	All	10m layer including MWSL	All
Category of fish	Demersal	Demersal	Demersal	Demersal + pelagic	Pelagic + demersal	Pelagic	Small pelagic
Lake depth zones (m)	10m	10m	ca 10m	10m	5m	10m	All
Survey area (km^2)	1618	5942	6255-6425	5942	6570	6255-6425	7560
Hydrocynus forskalii	574	74	-	-	143	-	+
Alestes baremose	22	1	-	-	16	-	+
Alestes ferox	+	13	-	-	97	-	54
Alestes minutus	+	+	-	-	63	-	1526
Micralestes acutidens	-	-	-	-	+	-	201
Labeo horie	64	9	19	9	1	-	+
Barbus bynni	180	93	103	207	23	-	+
Engraulicypris stellae	+	+	-	-	1	-	1799
Schilbe uranoscopus	114	57	44	185	156	-	+
Chrysichthys auratus	12	26	13	35	19	-	+
Bagrus bayad	901	1034	938	1139	1282	-	+
Synodontis schall	831	377	221	3984	264	-	+
Lates longispinis	91	531	310	1378	281	-	42 *
Lates niloticus	1792	647	410	2001	167	-	
Haplochromis macconneli	2	11	10	12	109	-	+
Others	363	32	-	-	17	-	157
Total	4946	2905	2070	8950	2638	37,000	3486

TABLE 8.31

Estimates of standing stock for important openwater species of fish in Lake Turkana expressed in tonnes. *Hydrocynus forskalii* and *Alestes baremose* have been omitted since no estimates of stock density are available.

Species	Depth zone < 10 m	> 10 m	All depths
Alestes ferox	300	18,400	18,700
Alestes minutus	3,000	184,000	187,000
Barbus bynni	200	1,200	1,400
Engraulicypris stellae	2,300	11,300	13,600
Schilbe uranoscopus	200	1,100	1,300
Chrysichthys auratus	20	210	230
Bagrus bayad	1,500	6,800	8,300
Synodontis schall	1,300	23,700	25,000
Lates longispinis	150	7,300	7,450
Lates niloticus	2,900	11,900	14,800
Lates spp. post-larvae	90	230	320
Haplochromis macconneli	30	690	720
TOTAL	11,990	266,830	278,820